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REVOLUTIONIZING PRE-CALCULUS EDUCATION: PHOTOMATH'S AI-POWERED MATHEMATICS TUTORSHIP

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Abstract

Mathematics plays a vital role in education; however, Filipino students encounter difficulties, evident in their performance on both national and international assessments. However, current literature suggests that leveraging technology, such as calculators and AI, in mathematics education can enhance students' proficiency, particularly in the pre-calculus domain. Thus, this research study examined the effectiveness of Photomath in enhancing Filipino students' self-reliance, interest, and performance in pre-calculus. A quasi-experimental one-group pretest-posttest design was used, with 49 Grade 11 students from NEUST Laboratory High School participating. Descriptive and inferential statistical analyses were performed to examine the pre-and post-intervention data. Results revealed a significant increase in students' self-reliance, interest, and performance in pre-calculus following the use of Photomath. The mean scores on all three measures increased significantly from the pretest to the posttest. The results of the t-tests further confirmed the effectiveness of Photomath in enhancing students' self-reliance, interest, and performance in pre-calculus. These results suggest that Photomath can be a valuable tool for educators to incorporate into pre-calculus teaching to enhance students' confidence and interest, foster intrinsic motivation, and ultimately improve their performance.
Keywords: *Photomath, students' interest, students' self-reliance, performance in pre-calculus*

Introduction

Mathematics is regarded as one of the most important disciplines in the academic curriculum since it is essential in many fields, including science, engineering, technology, economics, and business. However, many students struggle to understand and apply mathematical concepts and principles, particularly Filipino students (Capuno et al., 2019). Several studies have found that Filipino children struggle with mathematics, which is evident in their results on standardized assessments like the National Achievement Test (NAT) and the Programme for International Student Assessment (PISA). The Philippines placed 78th out of 79 participating nations in mathematical competency in the 2019 PISA assessment, with a mean score of 353, much lower than the worldwide mean score of 489.

Several factors may contribute to the challenges that Filipino students have when learning mathematics. One of the major issues is a lack of resources and assistance, particularly in rural areas where schools have limited access to quality textbooks, technology equipment, and competent teachers (Clifford, 2018; Child Hope, 2021). Another problem is the cultural perception of mathematics as a difficult and uninteresting topic, which may influence students' motivation and participation in learning (Grootenboer et al., 2015). Furthermore, the language barrier has a substantial impact on Filipino student's understanding of mathematical concepts. Because most mathematical concepts and principles are taught in English, students who are not competent in English may struggle to understand the topic, resulting in poor academic achievement (Jourdain & Sharma, 2016).

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A strong interest in the subject, on the other hand, can lead to greater academic performance (Sauer, 2012). According to Capinding (2021), students who are interested in mathematics are more likely to excel in the subject. Furthermore, Blotnicky et al., (2018) discovered that students who had greater interest in and skill for mathematics were more likely to pursue professions in STEM subjects. Moreover, studies have indicated that an interest or positive attitude in mathematics might benefit cognitive and brain development. For instance, Chen et al., (2018) found a connection between a favourable perspective towards mathematics and enhanced involvement of the hippocampal learning-memory system. Furthermore, students who participated in math-related activities had better working memory and executive functioning skills (Cortés Pascual et al., 2019).

Similarly, self-reliance is an essential trait for success in mathematical education. Learners who are self-reliant are more motivated, engaged, and persistent in their studies, and they are more equipped to tackle problems and hurdles in the learning process. Previous research emphasizes the significance of self-reliance in mathematics education and provides insights into how students might acquire this skill. Van der Bergh (2013) discovered that learners with self-confidence in mathematics were more likely to succeed academically. Özcan and Kültür (2021) discovered that self-efficacy plays a beneficial role in both performance on mathematics tests and overall achievement in mathematics courses. Furthermore, Bringula et al. (2021) showed that there is a positive correlation between mathematics learning autonomy and various academic outcomes, including achieving high grades, proficient problem-solving, ease in completing assignments, effective lesson recall, and outperforming peers or fellow students. Self-reliant learners were more motivated in their mathematics learning, resulting in greater success results (Davidovitch & Yavich, 2018).

According to Courtney et al., (2022), there is a positive correlation between students' favourable attitudes, confidence levels, belief in the utility of, and independent utilization of Information and Communication Technology (ICT), and their academic achievements in mathematics and science disciplines. In addition, technology plays a vital role in boosting student engagement, resulting in improved information retention, heightened self-esteem, and enhanced enthusiasm for learning (Singh, 2023). Moreover, the use of electronic devices can help increase student engagement, promote active learning, and enhance the learning experience (Ellis-Behnke, et al., 2005). Calculators are one of these electronic devices. Calculators have become a common tool in mathematics education, and students of all levels routinely use them. While some educators and parents are concerned that children's mathematical growth may be hampered by the use of calculators, previous research shows that calculators can be a useful tool in mathematics learning. According to Close et al., (2012) utilizing calculators in ninth-grade mathematics education was associated with higher levels of achievement and more positive attitudes about mathematics among students. In addition, Miles (2008) provided empirical evidence indicating that students who opt not to employ calculators tend to demonstrate inferior performance in solving fundamental mathematical problems in comparison to those who utilize calculators. Furthermore, according to Maxwell et al., (2004) using calculators in secondary school mathematics instruction can assist students in developing critical problem-solving abilities and boost their knowledge of mathematical ideas. Moreover, studies have shown that calculators can be especially useful for students who have learning disorders or issues with maths. For example, Russell (2014) found that the utilization of calculators enables students with learning disabilities to acquire essential mathematical concepts by mitigating the cognitive obstacles associated with recalling basic arithmetic facts.

Calculators may be more fascinating if they can answer problems in a more general manner, such as Artificial intelligence calculators. Artificial intelligence (AI) has become a common and influential tool in many areas, including education. In recent years, there has been a surge of interest in the use of AI in mathematics education. The potential benefits of AI in mathematics education are vast, including personalized learning experiences, improved student engagement, and enhanced problem-solving skills (Sinha, 2023). The use of AI in education can assist teachers in identifying and addressing the particular needs of their students, allowing for a more customized and effective approach to teaching (Singh & Hiran 2022). In recent years, the usage of online AI calculators in mathematics teaching has grown in popularity. Long and Bouck (2023) asserted that when employed appropriately and effectively, digital mathematics tools, including calculators and online games, have the potential to enhance students' conceptual comprehension of mathematical content, while also bolstering their confidence and active participation within the mathematics classroom. Moreover, the findings of Crawford et al. (2016) led to the conclusion that students encountering difficulties in mathematics can enhance their academic performance by incorporating electronic support tools to complement their existing knowledge, resulting in increased achievement.

However, not every research supports the use of calculators in mathematics instruction. Based on a survey conducted by Salani (2013), a majority of educators expressed concerns regarding the excessive reliance on calculators among students, which has the potential to hinder the acquisition of fundamental computational abilities. Similarly, Geisweit (2018) have argued that excessive dependence on calculators during secondary education can have detrimental effects on students' performance in college-level calculus. According to Close et al. (2008), while the utilization of calculators in mathematics classrooms has a notable positive influence on students' academic achievements, there exist certain drawbacks associated with their use. These include challenges in practical management, instances of improper or excessive reliance on calculators, difficulties in effectively utilizing calculators, and a potential decline in certain aspects of numerical literacy.

The Photomath is a well-known and widely used AI calculator. Photomath is a smartphone application that employs optical character recognition technology to solve mathematical problems instantaneously by taking a snapshot of the problem with the camera of a mobile device (Photomath, 2023). In recent times, there has been a surge in the app's popularity as a means for students to review their assignments, obtain step-by-step solutions, and for educators to facilitate teaching. Amparo et al. (2022) utilized Photomath as an educational tool in mathematics during online distance learning and found substantial evidence indicating an enhanced performance in students' mathematical abilities. Furthermore, Saundarajan et al. (2020) have showed that Photomath fosters learner independence and is regarded by students as an engaging approach to comprehending algebraic equations.

However, not all studies support the positive effect of Photomath in mathematics instruction. In a quasi-experimental study conducted by Igcasama et al. (2020), the impact of Photomath on the performance of grade 7 students in Elementary Algebra was examined. The findings revealed no notable disparity in the performance between students who utilized Photomath and those who did not. In addition, Latham (2020) argue that students who rely on Photomath and other online calculator for homework completion may fail to grasp essential concepts, resulting in a deficient foundation for their future learning. Furthermore, according to Muslimah et al. (2023), while Photomath has a favourable effect on students, it might make them lazy since students may rely only on Photomath answers rather than manually calculating. These findings suggest that the effectiveness of Photomath in mathematics education may be affected by a variety of factors, including students' mathematical proficiency, the type of mathematical tasks performed, the instructional methods used in conjunction with the app, the settings, students' level, and other internal or external factors.

The research aimed to address the challenges faced by Filipino students in understanding and applying mathematical concepts, as evidenced by their performance in national and international assessments. Based on the literature reviewed, the researcher sought to determine the beneficial effects of Photomath in increasing students' self-reliance, interest, and performance

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of Filipino students in mathematics (pre-calculus). The study specifically attempted to answer the following questions: How may the self-reliance, interest, and performance of the students in mathematics (pre-calculus) before and after the intervention of Photomath be described? Is there a significant difference in the students' self-reliance, interest, and performance in mathematics (pre-calculus) before and after the Photomath intervention?

Hypothesis: There is no significant difference in the students' self-reliance, interest, and performance in mathematics (pre-calculus) before and after the Photomath intervention.

Research Methodology

Research Design

The study utilized both descriptive and quasi-experimental one-group pretest-posttest design. The Descriptive research was utilized to determine the student's level of self-reliance and interest in learning mathematics (pre-calculus) before and after the intervention of Photomath. According to Cohen et al. (2018), descriptive research is a study that depicts and explains the features of a group or phenomena. On the other hand, the quasi-experimental one-group pretest-posttest design was used to determine the effectiveness of Photomath in enhancing students' self-reliance, interest and performance in mathematics (pre-calculus). A one-group pretest-posttest study is a type of quasi-experimental research in which one group of participants are tested both before and after an intervention on the same dependent variable (Price et al., 2015).

The research focus was delimited to assess the effect of Photomath on augmenting students' interest, self-reliance, and performance in the domain of pre-calculus. Moreover, the extrapolation of findings from this investigation will be contingent solely upon data derived from pre- and post-evaluations. Additionally, the study employed a one-group pretest-posttest design, acknowledged for its relatively limited robustness compared to other quasi-experimental designs due to the exclusive examination of a singular group of participants.

Sampling Technique

A non-probability sampling technique, specifically the purposive sampling approach, was used simply because the study used a quasi-experimental design. Purposive sampling, according to Patton (2014), is "selecting individuals or groups who are likely to have information relevant to the research question, based on the researcher's judgment about who can best provide that information" (p. 244).

Participants

The participants of the study were the 49 Grade 11 students of Nueva Ecija University of Science and Technology, Laboratory High School. The sample size is composed of 20 males and 29 females. These 49 students were selected because they are below average in terms of performance in pre-calculus. The researcher took various essential measures to guarantee anonymity and voluntariness in the study. Initially, participant identities were safeguarded by assigning distinct codes to each person, maintaining the confidentiality of their personal details throughout the research. Additionally, the voluntary aspect of participation was highlighted during the informed consent process, explicitly stating that individuals had the option to withdraw from the study at any time without facing repercussions. Furthermore, active encouragement of questions and clarifications was employed to ensure participants had a thorough understanding of the voluntary nature of their involvement.

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Experimental Procedure

Prior to implementing the intervention, the researcher examined the student's self-reliance, interest, and performance in mathematics 11(pre-calculus). A questionnaire developed by the researcher was used to measure self-reliance and interest. A pre-test was used to examine the students' mathematics performance before the intervention.

During the discussion, the researcher allows the students to use the program "Photomath" to validate their pre-calculus answers. Students may use the program during class discussions but not during real evaluations. The Photomath program was utilized to enhance the discussion and fully comprehend the content of the lesson. Furthermore, the researcher assigned homework to the students based on the topics taught and allowed them to utilize Photomath to verify their answers. In addition, students were permitted to employ the steps supplied by Photomath without relying on the steps presented by the researcher. After 6 weeks of intervention, the researcher examines the student's self-reliance and interest in learning pre-calculus. The post-test was also given to determine the student's performance following the intervention. Following the collection of all data, the researcher used the t-test to assess differences in the students' self-reliance, interest, and performance in mathematics 11 (pre-calculus) before and after the intervention of Photomath.

Materials and Instruments

The researcher developed the questionnaires for self-reliance and interest in learning pre-calculus. Both questionnaires use a 4-point Likert scale. The responses from the respondents were as follows: 4 - Strongly Agree (Very Positive), 3 – Agree (Positive), 2 – Disagree (Negative), 1 - Strongly Disagree (Very Negative). The pre-test and post-test, on the other hand, were based on the Dep-Ed pre-calculus module. The content and difficulty of the pre-test and post-test are comparable but the two tests are not identical.

Questionnaires Validity

The Lawshe content validity approach, developed by Lawshe (1975), was used to analyze the content validity of self-reliance and interest in learning mathematics (pre-calculus). It aids in determining if the items appropriately represent the construct being assessed and whether they are relevant to the assessment's intended objective. The following are the steps done in the validation of the instruments.

1. The researcher seeks the help of ten faculty members of NEUST Gabaldon to validate the questionnaire.
2. Experts were asked to score each item in the instrument independently based on its relevance to the construct being examined. To express their opinions, the experts utilized a rating range of 1 to 3. The responses of raters are as follows: 1 for non-essential, 2 for beneficial but not essential and 3 for essential.
3. The content validity ratio (CVR) of each item is computed as CVR = (Ne - N/2) / (N/2), where Ne is the number of experts who assessed the item as essential or relevant and N is the total number of experts in the panel. The content validity index is the average of all the items' CVR.
4. For ten raters, the critical value of CVR is 0.62. All items with a CVR value equal to or greater than the critical threshold are regarded as content valid and were retained in the instrument.

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Table 1 displays the content validity of each item as well as the content validity index for each component. The content validity of all items for self-reliance and interest in learning mathematics (pre-calculus) is greater than the critical value of 0.62, hence all items are considered valid. Furthermore, the content validity index demonstrates that the items were valid for measuring that construct.

Table 1
Validity of Each Item

	Self-reliance	**CVR Value**	**Interpretation**
1	I actively explore various resources, such as textbooks, online courses, and videos, to acquire new mathematical knowledge and enhance my comprehension of existing concepts.	1	Valid
2	I feel at ease recognizing and acknowledging areas where my mathematical skills may be lacking.	.8	Valid
3	I possess the ability to tackle challenging mathematical problems or concepts, even if they are not immediately clear to me.	1	Valid
4	I frequently seek feedback from educators, peers, or online forums to enhance my understanding of mathematical concepts.	.8	Valid
5	I exhibit effective time management skills while studying mathematics, and my study habits yield productive outcomes.	1	Valid
6	I am intrinsically motivated to continue my mathematical learning journey, particularly when encountering demanding problems or concepts.	.8	Valid
7	I can apply mathematical principles to real-life situations or problems.	1	Valid
8	I demonstrate resilience in the face of setbacks or errors when engaging with mathematical concepts.	1	Valid
9	I am proficient in monitoring my progress and setting goals for my mathematical learning.	1	Valid
10	I am capable of working independently or collaboratively with others as necessary when engaging in mathematical learning activities.	1	Valid
	Content Validity Index for Self-reliance	.94	Valid
	Interest in Learning Mathematics	CVR Value	Interpretation
1	I have a genuine interest in mathematics and find it both intriguing and enjoyable to learn.	1	Valid
2	I am driven to expand my knowledge of mathematics beyond the requirements of my coursework.	1	Valid
3	I possess a natural curiosity for mathematical concepts and take pleasure in exploring them.	1	Valid
4	Actively seeking out opportunities to deepen my understanding of mathematics is something I do willingly, even beyond what is expected in my academic pursuits.	1	Valid
5	Solving math problems brings me satisfaction, and I take pleasure in reaching solutions.	1	Valid
6	I have a keen interest in the practical applications of mathematics in real-world scenarios.	.8	Valid
7	Engaging in discussions about mathematical concepts with others and learning from their unique perspectives is something I greatly appreciate.	.8	Valid
8	The history and evolution of mathematical concepts captivate my interest, and I enjoy delving into them.	1	Valid

9	I view mathematics as a creative and intellectually stimulating discipline that demands critical thinking.	1	Valid
10	My enthusiasm for mathematics drives me to consider pursuing further studies in the subject, extending beyond the scope of my current coursework.	1	Valid
	Content Validity Index for Interest	.96	Valid

Difficulty Index and Discriminating Power of Each Test Item

Table 2 reveals that all of the items in the pre-test and post-test were classified as good or very good. The difficulty index is within the range of 0.3-0.71, suggesting that the items are of moderate difficulty, while the discriminating power is within the range of 0.3-0.71, showing that the items can discriminate between high- and low-performing participants.

Table 2
Items Difficulty Index and Discriminating Power

	Pre-Test			Post-Test		
Items	Difficulty Index	Discriminating Power	Verbal Interpretation	Difficulty Index	Discriminating Power	Verbal Interpretation
1	.41	.38	Good	.62	.42	Very Good
2	.41	.35	Good	.45	.68	Very Good
3	.55	.41	Very Good	.58	.55	Very Good
4	.56	.41	Very Good	.71	.70	Good
5	.57	.42	Very Good	.53	.62	Very Good
6	.65	.45	Very Good	.62	.39	Good
7	.41	.55	Very Good	.39	.70	Very Good
8	.57	.56	Very Good	.52	.58	Very Good
9	.67	.38	Good	.67	.51	Very Good
10	.7	.38	Good	.58	.68	Very Good
11	.66	.41	Very Good	.48	.47	Very Good
12	.37	.45	Very Good	.56	.63	Very Good
13	.39	.45	Very Good	.64	.49	Very Good
14	.42	.55	Very Good	.52	.54	Very Good
15	.43	.56	Very Good	.43	.71	Very Good
16	.41	.56	Very Good	.59	.59	Very Good
17	.52	.56	Very Good	.71	.65	Very Good
18	.55	.41	Very Good	.61	.53	Very Good
19	.58	.41	Very Good	.54	.57	Very Good
20	.59	.38	Good	.68	.66	Very Good
21	.61	.42	Very Good	.47	.48	Very Good
22	.66	.42	Very Good	.56	.61	Very Good
23	.67	.41	Very Good	.63	.52	Very Good
24	.64	.55	Very Good	.49	.56	Very Good
25	.65	.56	Very Good	.57	.39	Good

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26	.41	.35	Good	.66	.59	Very Good
27	.42	.41	Very Good	.51	.67	Very Good
28	.41	.41	Very Good	.59	.58	Very Good
29	.55	.41	Very Good	.44	.63	Very Good
30	.56	.42	Very Good	.63	.51	Very Good
31	.52	.56	Very Good	.51	.59	Very Good
32	.53	.55	Very Good	.57	.67	Very Good
33	.42	.38	Good	.65	.49	Very Good
34	.65	.38	Good	.48	.54	Very Good
35	.67	.41	Very Good	.55	.43	Very Good
36	.68	.41	Very Good	.62	.59	Very Good
37	.69	.41	Very Good	.46	.71	Good
38	.55	.55	Very Good	.58	.56	Very Good
39	.53	.56	Very Good	.69	.52	Very Good
40	.50	.56	Very Good	.53	.64	Very Good
41	.61	.55	Very Good	.61	.59	Very Good
42	.60	.41	Very Good	.50	.67	Very Good
43	.41	.42	Very Good	.56	.58	Very Good
44	.55	.42	Very Good	.64	.63	Very Good
45	.58	.42	Very Good	.48	.33	Good
46	.60	.41	Very Good	.59	.39	Good
47	.67	.55	Very Good	.42	.67	Very Good
48	.66	.56	Very Good	.62	.49	Very Good
49	.42	.56	Very Good	.50	.54	Very Good
50	.38	.41	Very Good	.57	.71	Good

Instruments Reliability

The questionnaires and test questions were pre-tested on 30 upper-secondary school students who were not involved in the study's participants. The reliability coefficients for self-reliance and interest in learning mathematics are 0.88 and 0.91, respectively. The reliability coefficients for the pre-test and post-test are 0.92 and 0.90, respectively. All instruments have a reliability coefficient that falls somewhere between good and excellent. Using SPSS-Cronbach's alpha, the reliability coefficient was evaluated.

Data Collection

Before conducting the study, the researcher obtained authorization from the principal of the Laboratory High School as well as the campus director of NEUST-Gabaldon. Before beginning the intervention, students were given survey questionnaires and a pre-test. After 6 weeks, the researcher re-evaluates the student's self-reliance and interest by administering the same questionnaire that was administered before the introduction of the intervention. A post-test was also administered to students to evaluate their performance in mathematics 11.

Data Analysis

The mean was used to describe the students' self-reliance and interest in learning mathematics (pre-calculus) before and after the intervention. Mean and standard deviation were used to describe students' math performance before and after the intervention. The dependent t-test was used to compare students' self-reliance, interest, and performance in mathematics (pre-calculus) before and after the intervention.

Data Normality Test

Table 3 depicts the data normality test. According to the Shapiro-Wilk test, students' self-reliance, interest, and performance in mathematics are normally distributed, thus the t-test was employed to examine the data.

Table 3
Test of Normality

	Shapiro-Wilk		
	Statistic	*df*	*p-value*
Pre-test	.886	49	.197
Post-test	.957	49	.070
Self-reliance Before	.969	49	.213
Self-reliance After	.898	49	.174
Interest in Learning Pre-Calculus Before	.982	49	.632
Interest in Learning Pre-Calculus After	.946	49	.263

Research Results

Students' Self-Reliance Before and After the Intervention of Photomath

Table 4 presents the mean and standard deviation for self-reliance before and after the intervention of Photomath. Prior to the implementation of Photomath, students exhibited favorable self-reliance, as indicated by their responses falling within the "agree" range (M = 2.57 to 2.92). Following the intervention, there was a notable enhancement in self-reliance, with mean responses for each item increasing to a level that can be characterized as highly positive (M = 3.41 to 3.73).

Additionally, the standard deviation for each item was observed to be higher before the intervention (SD = 0.54-0.80) compared to after the intervention (SD = 0.45-0.50). This reduction in standard deviation suggests a more consistent and uniform improvement in students' self-reliance post-Photomath intervention. The data clearly demonstrates an enhancement in students' self-reliance subsequent to the introduction of Photomath, and the reduced standard deviation indicates a convergence of responses in this regard.

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Table 4
Students' Self-Reliance Before and After the Intervention of Photomath

Self-reliance	Before			After		
	M	*SD*	Verbal Interpretation	*M*	*SD*	Verbal Interpretation
I actively explore various resources, such as textbooks, online courses, and videos, to acquire new mathematical knowledge and enhance my comprehension of existing concepts.	2.76	.69	Agree	3.45	.50	Strongly Agree
I feel at ease recognizing and acknowledging areas where my mathematical skills may be lacking.	2.57	.54	Agree	3.57	.50	Strongly Agree
I possess the ability to tackle challenging mathematical problems or concepts, even if they are not immediately clear to me.	2.63	.67	Agree	3.57	.50	Strongly Agree
I frequently seek feedback from educators, peers, or online forums to enhance my understanding of mathematical concepts.	2.92	.73	Agree	3.57	.50	Strongly Agree
I exhibit effective time management skills while studying mathematics, and my study habits yield productive outcomes.	2.90	.62	Agree	3.73	.45	Strongly Agree
I am intrinsically motivated to continue my mathematical learning journey, particularly when encountering demanding problems or concepts.	2.86	.61	Agree	3.43	.50	Strongly Agree
I can apply mathematical principles to real-life situations or problems.	2.65	.60	Agree	3.41	.50	Strongly Agree
I demonstrate resilience in the face of setbacks or errors when engaging with mathematical concepts.	2.73	.76	Agree	3.45	.50	Strongly Agree
I am proficient in monitoring my progress and setting goals for my mathematical learning.	2.84	.80	Agree	3.69	.47	Strongly Agree
I am capable of working independently or collaboratively with others as necessary when engaging in mathematical learning activities.	2.92	.67	Agree	3.53	.50	Strongly Agree
Total weighted mean	2.78	.27	Agree	3.54	.13	Strongly Agree

Students' Interest Before and After the Intervention of Photomath

Table 5 displays the mean values and standard deviations pertaining to students' levels of interest both before and after the intervention. The data indicated that prior to the intervention, students exhibited consensus on all aspects of their interest in learning mathematics, with mean values ranging from 2.65 to 2.88. This suggests a generally positive predisposition toward mathematics learning prior to the intervention.

Subsequent to the intervention, there was a notable increase in students' interest in pre-calculus, as evidenced by the rise in mean values to the range of 3.43 to 3.73. This indicates a heightened positive interest among students in the subject following the intervention.

Furthermore, it is worth noting that the standard deviation associated with students' responses witnessed a reduction after the implementation of Photomath (*SD before* = 0.58-0.80; *SD after* = 0.45-0.50), signifying a greater convergence in students' responses.

Table 5
Students' Interest Before and After the Intervention of Photomath

Interest	Before			After		
	M	*SD*	Verbal Interpretation	*M*	*SD*	Verbal Interpretation
I have a genuine interest in mathematics and find it both intriguing and enjoyable to learn.	2.71	.65	Agree	3.57	.50	Strongly Agree
I am driven to expand my knowledge of mathematics beyond the requirements of my coursework.	2.80	.58	Agree	3.57	.50	Strongly Agree
I possess a natural curiosity for mathematical concepts and take pleasure in exploring them.	2.88	.70	Agree	3.57	.50	Strongly Agree
Actively seeking out opportunities to deepen my understanding of mathematics is something I do willingly, even beyond what is expected in my academic pursuits.	2.67	.72	Agree	3.73	.45	Strongly Agree
Solving math problems brings me satisfaction, and I take pleasure in reaching solutions.	2.86	.61	Agree	3.43	.50	Strongly Agree
I have a keen interest in the practical applications of mathematics in real-world scenarios.	2.73	.67	Agree	3.73	.45	Strongly Agree
Engaging in discussions about mathematical concepts with others and learning from their unique perspectives is something I greatly appreciate.	2.65	.72	Agree	3.45	.50	Strongly Agree
The history and evolution of mathematical concepts captivate my interest, and I enjoy delving into them.	2.71	.58	Agree	3.39	.49	Strongly Agree
I view mathematics as a creative and intellectually stimulating discipline that demands critical thinking.	2.78	.65	Agree	3.45	.50	Strongly Agree
My enthusiasm for mathematics drives me to consider pursuing further studies in the subject, extending beyond the scope of my current coursework.	2.67	.80	Agree	3.67	.47	Strongly Agree
Total weighted mean	2.75	.25	Agree	3.56	.17	Strongly Agree

Students' Performance Before and After the Intervention of Photomath

Table 6 presents an overview of student performance both before and after the implementation of the Photomath intervention. The data revealed that the pretest score (*M* =

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18.2653) is lower than the posttest score (*M* = 29.12), indicating a noteworthy improvement in student performance following the introduction of Photomath.

Furthermore, it is noteworthy that the standard deviation observed after the intervention has decreased (*SD before* = 5.53; *SD after* = 1.49). This reduction implies that student scores have become more closely clustered around the mean, suggesting a greater consistency in their performance outcomes.

Table 6
Students' Performance Before and After the Intervention of Photomath

	M	*N*	*SD*
Pre-test	18.26	49	5.53
Post-test	29.12	49	1.49

Comparison of Students' Performance, Self-Reliance and Interest in Learning Mathematics Before and After the Intervention of Photomath

Table 7 provides statistical insights into the impact of the Photomath intervention on self-reliance, interest, and performance. The mean differences for self-reliance ($t(48) = -17.66$, $p < 0.01$), interest ($t(48) = -20.87$, $p < 0.01$), and performance ($t(48) = -9.58$, $p < 0.01$) before and after the intervention are highly significant. These findings indicate a substantial increase in students' levels of self-reliance, interest, and performance following the implementation of Photomath.

The results of the t-tests underscore the enhancement of self-reliance and interest among students after the intervention, suggesting that students have become more self-sufficient and exhibit a heightened enthusiasm for engaging with pre-calculus problems. Furthermore, there is a significant improvement in students' performance, attributing this positive change to the effect of the intervention.

Table 7
Comparison of Students' Performance, Self-Reliance and Interest in Learning Pre-Calculus Before and After the Intervention of Photomath

	M	*Mean Difference*	*df*	*t*	*p-value (2-tailed)*
Self-reliance Before	2.78	-0.76	48	-17.66	< .001
Self-reliance After	3.54				
Interest Before	2.75	-0.81	48	-20.87	< .001
Interest After	3.56				
Pretest	18.27	-10.85	48	-9.58	< .001
Posttest	29.12				

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Discussion

The findings presented in Table 4 shed light on the impact of the Photomath intervention on students' levels of self-reliance in the context of mathematics education. These results not only affirm the effectiveness of the intervention but also provide insights into the dynamics of students' self-reliance and their responses to this transformative educational tool.

Before the implementation of Photomath, students exhibited a favorable level of self-reliance, as indicated by their responses consistently falling within the "agree" range (M = 2.57 to 2.92). This baseline level of self-reliance suggests that students possessed a foundational degree of confidence in their own abilities and autonomy in learning mathematics. While these initial levels were promising, there was room for further enhancement.

Following the intervention, a notable and noteworthy increase in self-reliance became evident, with mean responses for each item rising to a level characterized as highly positive (M = 3.41 to 3.73). This post-intervention surge in self-reliance reflects the transformative potential of technology-assisted learning tools like Photomath in empowering students to take greater ownership of their learning process (Photomath, 2023). The heightened self-reliance is particularly promising, as it indicates that students not only improved their mathematical skills but also developed a more confident and self-assured approach to problem-solving. According to a study undertaken by Riski et al. (2021), a significant majority of students, specifically 80%, concur that the utilization of Photomath has the potential to foster increased self-reliance within the realm of mathematics education. This effect is particularly pronounced in the context of SLETV (Science, Language, English, Technology, and Vocational) materials.

An additional noteworthy observation is the reduction in standard deviation for each item after the intervention (*SD before* = 0.54-0.80; *SD after* = 0.45-0.50). This decrease implies that students' responses became more closely clustered around the mean, indicating a convergence in their levels of self-reliance. The reduced variability in responses suggests that the Photomath intervention not only increased overall self-reliance but also had a harmonizing effect on students' perceptions of their own capabilities. This phenomenon may be attributed to the intervention's ability to provide consistent, step-by-step guidance, thus influencing students' attitudes and self-reliance in a similar positive direction.

The findings presented in Table 5 shed light on the transformative impact of the Photomath intervention on students' levels of interest in pre-calculus. These results not only highlight the effectiveness of the intervention but also provide insights into the dynamics of students' attitudes and perceptions towards mathematics learning.

Prior to the intervention, students exhibited a relatively consistent and positive predisposition towards learning mathematics, as evidenced by the mean values ranging from 2.65 to 2.88. This baseline positivity suggests that students possessed a foundational interest in mathematics, but there was room for improvement and enhancement of their enthusiasm for the subject. It is noteworthy that even before the intervention, students generally held a favorable view of mathematics, which provides a strong starting point for educational interventions.

Subsequent to the implementation of the Photomath intervention, a striking increase in students' interest in pre-calculus became evident. The mean values surged to a range of 3.43 to 3.73, indicating a substantial and noteworthy elevation in students' positive interest levels towards the subject. This post-intervention shift in interest reflects the potential of technology-assisted learning tools like Photomath in revitalizing and rekindling students' engagement with mathematics. The increased interest observed is particularly promising, as heightened enthusiasm can have cascading effects on motivation, participation, and ultimately, academic performance (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018).

The reduction in standard deviation associated with students' responses after the intervention (*SD before* = 0.58-0.80; *SD after* = 0.45-0.50) is a notable observation. This decline implies that students' responses became more tightly clustered around the mean, indicating a convergence in their levels of interest. The decreased variability in responses suggests that the Photomath intervention not only increased overall interest but also had a unifying effect on students' perceptions of pre-calculus. This phenomenon may be attributed to the intervention's ability to provide consistent and structured support, thereby influencing students' attitudes in a similar, positive direction.

The findings presented in Table 8 provide valuable insights into the impact of the Photomath intervention on student performance in the context of this study. The observed increase in posttest scores compared to pretest scores signifies a noteworthy improvement in student performance following the implementation of the Photomath intervention. This outcome aligns with the overarching objective of the intervention, which aimed to enhance students' proficiency in the subject matter, in this case, pre-calculus. The mean pretest score of 18.2653 significantly rose to 29.12 in the posttest, highlighting the effectiveness of Photomath in elevating student achievement. Similarly, Igcasama et al. (2020) demonstrated a noteworthy positive impact on students' mathematics performance through the application of Photomath as an instructional tool, although it did not yield complete superiority when contrasted with the conventional teaching approach. In addition, research by Serin (2011) suggests that technology-based assisted instruction (TBAI) can improve student achievement and problem-solving skills.

One particularly observation is the reduction in the standard deviation (SD) of scores after the intervention (*SD before* = 5.53; *SD after* = 1.49). This decrease implies that student scores have become more closely clustered around the mean, indicating a greater consistency in their performance outcomes. This reduction in variance suggests that the Photomath intervention not only improved overall performance but also promoted more uniform achievement levels among students. This outcome has important implications for educators and policymakers aiming to reduce performance disparities within student populations.

The mean difference of -17.66 ($t(48)$) with a highly significant p-value of $p < .001$ suggests that the Photomath intervention significantly increased self-reliance among participants in the context of pre-calculus. This is a notable finding because pre-calculus is a subject that often requires students to grapple with complex mathematical concepts and problem-solving independently. Enhanced self-reliance in pre-calculus can lead to students being more confident in tackling challenging mathematical problems on their own, seeking out help only when truly needed. According to Gardner-Neblett et al. (2014), self-reliant behaviors exhibited in the classroom were indicative of subsequent alterations in mathematics proficiency during adolescence. It can also promote a deeper understanding of the subject matter by encouraging students to actively engage with the material. These skills are not only valuable in pre-calculus but are transferable to other educational domains and real-life problem-solving situations.

The mean difference of -20.87 ($t(48)$) with a highly significant p-value of $p < .001$ highlights that the Photomath intervention had a substantial positive impact on participants' interest in pre-calculus. Pre-calculus often feels quite challenging to many students, and when they don't find it engaging or interesting, it can really dampen their motivation to learn. When students become more interested, it can set off a chain reaction of positive effects on their learning (Harackiewicz et al., 2016). When they genuinely like the subject, they tend to get more involved in class, spend more time studying on their own, and keep going even when they encounter difficulties. In addition, students who are more engaged in their studies tend to perform better academically (Lei et al., 2018). This mirrors what we see in educational research, which underscores the significance of inner motivation in the learning process.

The mean difference of -9.58 ($t(48)$) with a highly significant p-value of $p < .001$ demonstrates that the Photomath intervention led to a substantial improvement in participants' performance in pre-calculus. Improved performance in pre-calculus is of paramount importance, as this subject serves as a foundational precursor to more advanced mathematics and science courses. Zain et al. (2023) similarly demonstrate congruent results, wherein the utilization of Photomath as an intervention leads to an elevation in both student performance and their levels of interest in mathematics learning.

The link between interest, self-reliance, and performance in pre-calculus is well-established. Increased interest and self-reliance likely drove students to put in more effort and practice, resulting in better performance. This reinforces the idea that interventions targeting interest and self-reliance can have a significant impact on academic achievement.

Conclusions and Implications

This study highlights the significant potential of technology-assisted learning, as demonstrated by the Photomath intervention, within the domain of pre-calculus education. The marked improvements observed in self-reliance, interest, and performance underscore the capacity of such interventions to empower students by fostering greater self-direction, intrinsic motivation, and proficiency in mathematics. These findings carry substantial implications for educators seeking innovative strategies to engage students and elevate educational outcomes. While recognizing the study's inherent limitations, notably the modest sample size and short-term focus, the encouraging results warrant attention and suggest a promising avenue for future research and pedagogical strategies. Embracing technology as a complementary educational tool holds promise for equipping students with the requisite skills and motivation for success in the demanding landscape of pre-calculus and, correspondingly, in their broader academic and professional pursuits. Furthermore, the study demonstrates a significant improvement in pre-calculus performance following the Photomath intervention, as reflected in increased posttest scores and a reduced standard deviation. The intervention not only enhanced overall student achievement but also promoted more uniform outcomes. The findings align with previous research, highlighting Photomath's positive effect on mathematics learning.

Recommendations

Based on the compelling findings, it is recommended that educators incorporate technology-assisted learning tools such as Photomath into pre-calculus instruction to enhance students' self-reliance, interest, foster intrinsic motivation, and ultimately improve their performance. Educators should provide guidance on effective tool utilization, encourage independent problem-solving, and infuse real-world relevance into the curriculum. Students are encouraged to proactively engage with technology resources, cultivate their interest in mathematics, and develop self-reliance as a crucial skill. Long-term follow-up studies should be conducted to assess the sustainability of these effects, and further research should delve into the mechanisms underlying technology-based interventions' impact on mathematical learning. In addition, researchers should aim for larger, more diverse samples, and educational institutions should offer professional development opportunities to empower educators with the skills needed for successful integration of such tools. These recommendations collectively aim to harness the potential of technology in mathematics education to benefit both students and educators.

Limitations

While these findings are promising, there are some limitations to consider. The study's sample size is relatively small ($N = 49$), and the specific demographics of the participants may influence the generalizability of the results. Moreover, this study primarily focused on short-term effects immediately after the intervention. Long-term follow-up studies would be valuable to assess the sustainability of the observed changes in self-reliance, interest, and performance.

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