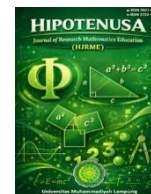


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The effectiveness of using photomath in improving mathematics learning outcomes and learning interest among grade students

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ABSTRACT

Mathematics is a subject that plays a crucial role in developing logical and analytical thinking skills. However, students' learning outcomes and interest in mathematics remain relatively low. One approach to address this issue is to utilize educational technology, such as the Photomath app. This study aims to determine the effectiveness of using the Photomath app on students' learning outcomes and interest in mathematics. The study employed a quantitative approach with a quasi-experimental design of the nonequivalent control group type, involving three groups: an experimental group, a combination group, and a control group. The research instruments consisted of a learning outcomes test and a learning interest questionnaire. Data were analyzed using One-Way ANOVA, Tukey's Post Hoc test, and MANOVA. The results showed that there was a significant difference in mathematics learning outcomes among the groups based on the One-Way ANOVA test ($F(2,87) = 30.157; p < 0.001$). The Tukey test results indicated that the experimental group had significantly higher learning outcomes compared to the other groups. Furthermore, the MANOVA results indicate that the use of Photomath simultaneously influences both students' learning outcomes and their interest in learning. Thus, the Photomath app is effective as a learning medium for improving students' mathematics learning outcomes and interest in learning. Future research is recommended to include other variables, different educational levels, and a longer treatment duration to obtain more comprehensive findings.

1. Introduction

Digital technology advancements have significantly altered many facets of society, including education. Technology is now used in education to create a more dynamic, efficient, and learner-centered process rather than just as a means of material delivery. The use of technology in mathematics education has grown in significance because it facilitates students' comprehension of abstract ideas through simulation, visualization, and the methodical presentation of problem-solving

techniques. In line with the revised Bloom's Taxonomy, creative thinking skills fall under the highest cognitive level (creating), which requires students to generate new ideas, strategies, or solutions to solve problems [1]. Therefore, mathematics education in the digital age is expected to leverage technological advancements to support the development of higher-order thinking skills while enhancing the quality of the learning process.

Technology is playing an increasingly significant role in mathematics education because it can improve students' comprehension of ideas and increase their level of involvement [2]. Explains

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that the use of technology in mathematics education contributes positively to improving the effectiveness of learning and student participation. In line with this view, the objectives of mathematics education focus not only on computational skills but also on developing logical, analytical, critical, and creative thinking skills, as well as the ability to solve problems that students encounter in their daily lives [3].

Mathematics education is also closely linked to various real life contexts, so presenting material in a contextual manner can help students build a more meaningful conceptual understanding. Indicates that mathematical concepts can be found in cultural activities through the study of ethnomathematics, such as the Lahbako dance, which represents geometric concepts [4]. Furthermore, found that the use of visual media in the form of image-based Sudoku can enhance students' understanding of number concepts while simultaneously training their systematic thinking skills [5]. On the other hand, reveals that context-based learning and hybrid learning positively contribute to the development of critical thinking skills among prospective mathematics teachers [6]. These diverse results show that the integration of technology and cutting-edge educational materials can produce more meaningful learning experiences, motivating students to take an active role in creating their own knowledge.

Mathematics teaching in schools still faces a number of obstacles despite the development of multiple learning technologies. Because mathematics is full of abstract ideas, symbols, and intricate problem-solving techniques, many students view it as a challenging subject. poor arithmetic achievement is the outcome of students' lack of confidence, lack of engagement during the learning process, and comparatively poor enthusiasm in learning. Additionally, a teacher-centered approach still dominates the classroom learning process, which restricts students' ability to independently investigate issues. As a result, it is necessary to use technology-based learning resources that can boost students' attention and learning outcomes while gradually assisting them in understanding mathematical ideas.

The Photomath app is one such technology-based learning tool that has grown significantly in recent years. Photomath is an Artificial Intelligence (AI)-based math learning app that can recognize math problems through a smartphone camera and then automatically provide solutions along with step-by-step explanations. This finding aligns with the research [7], which shows that implementing an Artificial Intelligence (AI)-based learning model through the Contextual Teaching and Learning (CTL) approach yields higher average mathematics learning outcomes compared to the Project-Based Learning (PjBL) model. These results indicate that the integration of AI-based technology has the potential to enhance the effectiveness of mathematics learning. These features allow

students to receive immediate feedback, understand the problem-solving process systematically, and explore various alternative solution strategies; thus, the app functions not only as a tool for obtaining answers but also as a learning medium that supports the understanding of mathematical concepts [8].

Because students may compare their own problem-solving techniques with the steps provided by the app, using Photomath has the potential to enhance the quality of mathematics education. Through this process, conceptual and procedural errors can be identified more quickly, giving students the opportunity to correct their understanding independently. Indicates that the use of Photomath has a positive impact on mathematical problem-solving skills because students receive immediate feedback while working on problems [9]. These results show that Photomath has the potential to be a learning aid that facilitates a more autonomous, active, and concept-focused learning process.

Numerous earlier research have demonstrated that using digital media and educational software enhances the standard of mathematics instruction. Through a systematic literature review, concluded that the Photomath app can help students understand mathematical concepts by systematically presenting the steps to solve problems [8]. These findings indicate that Photomath has the potential to serve as a learning tool that makes it easier for students to understand mathematical material. Furthermore, found that the use of Photomath has a positive impact on mathematical problem solving skills because students receive immediate feedback during the problem-solving process [9].

Numerous other studies, in addition to those that concentrate on Photomath specifically, demonstrate how the application of technology and cutting-edge educational materials can raise the standard of mathematics instruction. States that the use of technology can enhance the effectiveness of mathematics learning [2]. Demonstrates that culturally context-based mathematics learning can improve conceptual understanding through more meaningful learning experiences [4]. Shows that the use of visual media can enhance students' understanding of number concepts as well as their ability to think systematically [5]. Furthermore, reveals that technology-based learning through contextual and hybrid learning approaches makes a positive contribution to improving students' critical thinking skills [6]. The use of instructional technology can enhance the quality of the learning process and promote the development of higher-order thinking skills, as these numerous research findings show.

However, a review of prior research indicates that there are still a number of research gaps. First, the majority of research only look at one dependent variable, such as learning motivation, problem-solving skills, or learning outcomes; as a result, they don't give a comprehensive picture of how

Photomath use affects both learning outcomes and learning interest. Second, systematic literature reviews and straightforward two-group experiments continue to dominate Photomath research; as a result, there are still few studies that compare the efficacy of using Photomath alone, Photomath in conjunction with conventional learning, and conventional learning without the app's assistance. Third, prior research has typically employed univariate statistical analysis, making it impossible to explain how Photomath use affects multiple dependent variables at once. Additionally, there is still a dearth of empirical evidence on the usage of Photomath among high school students in the eleventh grade, especially with relation to quadratic equations and functions.

Based on previous studies, several research gaps remain. Examines the use of Photomath through a systematic literature review without conducting empirical testing [8], while analyzes only the effect of Photomath on mathematical problem-solving skills [9]. The studies at [2,4,5,6], also discuss the use of different technologies or mathematics learning media; thus, they have not specifically tested the effectiveness of Photomath on both learning outcomes and interest in learning simultaneously. Also reveals that the implementation of the Lesson Study Cycle combined with Project-Based Learning can enhance student engagement and digital literacy through the use of various digital platforms during the learning process [10]. These results suggest that incorporating digital technology improves the quality of the educational experience. Thus, this study is novel in that it uses a quasi-experimental nonequivalent control group design with three research groups (experimental, combination, and control) to empirically test the impact of the Photomath app on learning outcomes and interest in mathematics simultaneously. The results are analyzed using a combination of One-Way ANOVA, Tukey's Post Hoc, and MANOVA to provide a more complete picture of Photomath's influence.

The following research topics are put forth in this study in light of this history and the current research gap. (1) Do students who use Photomath, a combination of Photomath and traditional instruction, or conventional instruction alone have different learning results in mathematics? (2) Do students who use Photomath, a mix of Photomath and traditional instruction, or conventional instruction alone have different levels of enthusiasm in learning mathematics? (3) Does the employment of Photomath affect students' enthusiasm in learning and their learning outcomes in mathematics at the same time?

The following research hypotheses are put out in response to these research questions. H1: Students that use Photomath, a mix of Photomath and conventional instruction, or conventional instruction alone have different learning results in mathematics. H2: Students who use Photomath, a mix of Photomath and conventional instruction, or

conventional instruction alone have different levels of enthusiasm in learning mathematics. H3: Students' motivation in learning and their learning outcomes in mathematics are both impacted by using Photomath.

According to these theories, the study's goals are to examine how the three learning groups' mathematics learning outcomes differ, how the three learning groups' students' interest in learning differs, and how using Photomath simultaneously affects both students' interest in learning and their math learning outcomes. The findings of this study are anticipated to make a theoretical contribution by adding to the body of knowledge on the application of AI-based technology in mathematics education, as well as to help teachers choose instructional materials that will enhance the caliber of the learning process and results.

2. Method

2.1. Research Design

This study employed a quantitative approach using a quasi experimental method with a nonequivalent control group design. This design was chosen because the study was conducted in existing classes, making it impossible for the researcher to fully randomize the subjects (true experimental design). Nevertheless, this design still allows the researcher to compare students' initial conditions through a pre-test, provide different treatments to each group, and evaluate changes in learning outcomes and interest in learning through a post-test and a questionnaire after the treatments were administered.

The study was conducted from November to December 2025 at SMAI Nurul Huda Bondowoso, East Java. The selection of this school was based on initial observations indicating that students' mathematics learning outcomes were still relatively low. Additionally, the school administration granted permission and provided support for the study, including the use of the Photomath app as a learning tool throughout the research process. The study took place in 11th grade, which consisted of three parallel classes: XI A, XI B, and XI C. The assignment of research groups was based on the classes designated by the school without individual randomization. Class XI A was designated as the experimental group, XI B as the combination group, and XI C as the control group.

The study involved three groups: the experimental group, the combined group, and the control group. The experimental group received mathematics instruction using the Photomath app as the primary learning medium. The combined group received conventional instruction integrated with the use of the Photomath app, while the control group received conventional instruction without using the Photomath app. The intervention was administered over four sessions covering quadratic

equations and functions.

Before the interventions were administered, all groups took a pre-test to assess students' initial abilities and completed an initial learning interest questionnaire. After the entire learning sequence was completed, students took a post-test and completed a final learning interest questionnaire to determine changes in learning outcomes and learning interest following the interventions.

Table 1

The research design used is shown in

Group	Pre-test	Treatment	Post-test
Experimental	O ₁	X ₁ (Learning using Photomath)	O ₂
Combination	O ₁	X ₂ (Conventional learning combined with Photomath)	O ₂
Control	O ₁	X ₃ (Conventional learning)	O ₂

2.2. Research Subjects

During the odd semester of the 2025–2026 school year, 11th graders at SMAI Nurul Huda in Bondowoso, East Java, participated in the study. Three classes of ninety students in the eleventh grade made up the study population. Total sampling, a sampling strategy that uses every member of the population as a research subject, was used to include every member of the population in the study sample.

Total sampling was chosen because the population size was relatively small and all classes shared comparable characteristics based on the curriculum, learning materials, and teaching methods implemented at the school. Using the entire population as the sample also aimed to reduce sampling bias and provide a more representative picture of the impact of the Photomath app on students' learning outcomes and interest in mathematics.

Students in the 11th grade who followed the same curriculum and were roughly 16 to 17 years old participated in the study. Throughout the trial, all individuals got the same amount of instruction on quadratic equations and functions. Following that, these pupils were split up into three research groups, each with thirty students: the experimental group, the combination group, and the control group. The Photomath app was used to train the experimental group, conventional instruction was given to the combination group together with the Photomath app, and conventional instruction was given to the control group without the Photomath app. According to the features of the nonequivalent control group quasi-experimental design, group assignment was based on classes chosen by the school.

2.3. Research Instruments

Learning accomplishment assessments and learning interest surveys were used to gather research data before and after the intervention. The

learning accomplishment tests were used as pre-tests and post-tests to gauge students' starting and finished skills following their participation in the lesson. In the meantime, utilizing the learning models that were applied to each group, learning interest questionnaires were given at the start and finish of the lesson to ascertain changes in students' learning interest after the instructional process.

The learning outcomes for quadratic equations and functions, which pertain to the cognitive process aspects in the updated Bloom's Taxonomy understanding (C2), applying (C3), and analyzing (C4) were the basis for the development of the accomplishment assessments. Twenty multiple-choice questions made up the test instrument, which was utilized for both pre-tests and post-tests. A student could receive a maximum score of 100 because each right response received a value of 5, while erroneous responses received a score of 0. Table 2 displays the test blueprint.

Table 2

Learning Outcome Test Blueprint

Indicator	Cognitive Domain	Question Numbers
Understanding the concepts of quadratic equations and functions	C2	1, 4, 5, 11, 14, 15, 20
Applying concepts to problem-solving	C3	3, 6, 7, 10, 12, 17, 18, 19
Analyzing the characteristics of quadratic equations and functions	C4	2, 8, 9, 13, 16

Examples of test items assessing learning outcomes are as follows. Sample Question: "The roots of the equation ($x^2 - 7x + 10 = 0$) are"

The learning interest instrument was developed based on the theory of learning interest [11], which includes four indicators: (1) enjoyment of learning mathematics, (2) attention during lessons, (3) interest in studying the material further, and (4) active involvement in the learning process. The questionnaire consists of 10 statements using a four-point Likert scale: Strongly Disagree (SD), Disagree (D), Agree (A), and Strongly Agree (SA). Scores are assigned sequentially from 1 to 4; thus, the higher the score obtained, the higher the level of students' interest in learning. The learning interest questionnaire item list is presented in Table 3.

Table 3

Learning Interest Questionnaire Matrix

Indicator	Pre-test Item Numbers
Enjoyment	1, 3
Attention	2, 4
Interest	5, 6, 10
Active participation	7, 8, 9

Examples of survey items used in the study are as

follows. Example Statement: “I am interested in studying the math material on quadratic equations.”

Before being used in the study, all instruments first underwent a content validity validation process by experts to assess the appropriateness of the indicators, content, language, and constructs of the instruments. Next, the instruments were pilot-tested on students outside the research sample. The validity of each instrument item was analyzed using the Pearson Product-Moment test, while the reliability of the instruments was analyzed using Cronbach's Alpha coefficient. Instruments that met the validity and reliability criteria were then used as research instruments.

2.4. Research Procedure

The research was conducted through several systematically organized stages. The first stage began with a preliminary study to identify mathematics learning problems at SMAI Nurul Huda Bondowoso, followed by a literature review and the development of instructional materials and research instruments. All instruments were then validated by experts and pilot-tested before being used in the study.

experimental treatments, data collection, and statistical analysis.

During the implementation stage, all research groups were administered a pre-test to measure students' initial abilities and an initial learning interest questionnaire to determine their level of learning interest before the interventions were administered. Subsequently, the learning process was conducted over four sessions covering quadratic equations and functions. The experimental group participated in learning using the Photomath app; the combination group followed conventional instruction integrated with Photomath; and the control group participated in conventional instruction without using Photomath.

After all treatments were completed, students in all three groups took a post-test using an instrument equivalent to the pretest to measure learning outcomes following the instruction. Subsequently, students completed a final learning interest questionnaire to determine changes in their learning interest after participating in the learning process. The data obtained from the pre-test, post-test, and questionnaires were then analyzed using statistical analysis techniques appropriate for the research objectives. The research procedure flowchart is presented in the following Fig. 1.

2.5. Data Analysis Techniques

The data obtained from the pre-test, post-test, and learning interest questionnaire were analyzed using IBM SPSS Statistics software. The analysis began with descriptive statistics to describe the data characteristics, including the mean, maximum value, minimum value, and standard deviation for each research group. MANOVA was chosen because this study has two dependent variables—learning outcomes and learning interest—which were analyzed simultaneously. The use of MANOVA allows for testing the effect of the treatment on both dependent variables at the same time, making the process more efficient and reducing the likelihood of Type I errors compared to conducting multiple separate ANOVA tests.

The Shapiro-Wilk test for normality and Levene's test for homogeneity of variances were used to verify that the data satisfied the parametric analytic assumptions prior to hypothesis testing. Additionally, as one of the requirements for MANOVA analysis, a test for homogeneity of covariance matrices was carried out using Box's M test before multivariate analysis.

Testing of hypotheses was done in phases. The research groups' learning outcomes were compared using One-Way Analysis of Variance (One-Way ANOVA). Tukey's Post Hoc test was used in the analysis to find pairs of groups with significant differences if significant differences were discovered. The simultaneous impacts of utilizing the Photomath app on learning outcomes and interest in learning were then examined using Multivariate Analysis of



Fig. 1. Research procedure encompassing participant selection, instrument development,

Variance (MANOVA). A significance level of 0.05 was used for all hypothesis testing.

3. Results

3.1. Results of the Descriptive Analysis of Pre-test and Post-test

Descriptive analysis was conducted to determine the initial profile of students' abilities before the instructional intervention and changes in learning outcomes after the instructional process took place. The data analyzed included pretest and posttest scores for the three study groups: the experimental group, the combination group, and the control group.

Table 4
Mean Pre-test and Post-test Scores.

Group	Statistic	Pre-test Score	Post-test Score	Improvement
Experimental	Mean	61.6500	84.8133	23.1633
	N	30	30	30
	Standard deviation	3.60754	3.71954	4.92611
Combination	Mean	63.1533	78.5133	15.3600
	N	30	30	30
	Standard deviation	3.97681	3.64509	5.77256
Control	Mean	61.4233	73.5133	12.0900
	N	30	30	30
	Standard deviation	4.09294	3.79961	6.24568
Total	Mean	62.0756	78.9467	16.8711
	N	90	90	90
	Standard deviation	3.93044	5.92936	7.30043

Table 4 shows that there were no discernible variations between the three groups' pretest mean scores. This suggests that prior to the intervention, the students' starting skills were largely similar. All research groups saw an increase in posttest results following the learning process. The experimental group who utilized the Photomath app during the learning process, however, showed the largest growth. There was a 23.16 point rise for the experimental group, a 15.50 point gain for the combination group, and a 10.60 point increase for the control group.

These results indicate that the use of the Photomath app in mathematics instruction has the potential to yield higher learning outcomes compared to conventional teaching methods.

3.2. Result of the One-Way ANOVA Test

After the treatment was given, a one-way ANOVA was used to see if the experimental group, combination group,

and control group had different learning results in mathematics. Table 2 displays the analysis's findings.

Table 5
Results of the One-Way ANOVA

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1,942.036	2	971.018	30.157	< .001
Within Groups	2,801.329	87	32.199		
Total	4,743.365	89			

The F-value was determined to be 30.157 with a significance level of 0.000 ($p < 0.05$) based on Table 5. This finding suggests that the three research groups' pupils' learning outcomes in mathematics varied significantly from one another. As a result, the alternative hypothesis (H_1) is supported and the null hypothesis (H_0) is rejected, suggesting that students' learning outcomes in mathematics are impacted by the usage of various learning models. Tukey's post hoc test was used to continue the study in order to identify which groups displayed significant differences; the findings are shown in Table 6.

Table 6
Results of the Tukey Post Hoc Test

(I) Group	(J) Group	Mean Difference (I-J)	Standard Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Experimental	Combination	7.80333*	1.46513	< .001	4.3098	11.2969
	Control	11.07333*	1.46513	< .001	7.5798	14.5669
Combination	Experimental	-7.80333*	1.46513	< .001	-11.2969	-4.3098
	Control	3.27000	1.46513	.071	-0.2236	6.7636
Control	Experimental	-11.07333*	1.46513	< .001	-14.5669	-7.5798
	Combination	-3.27000	1.46513	.071	-6.7636	0.2236

The mean difference is statistically significant at the 0.05 level.

Based on the results of the Tukey test, the experimental group showed significant differences compared to the combination group (*Mean Difference* = 7.803; $p = 0.000$) and the control group (*Mean Difference* = 11.073; $p = 0.000$). Meanwhile, the combination group did not show a significant difference from the control group (*Mean Difference* = 3.270; $p = 0.071$). These results indicate that the full use of the Photomath app leads to a greater improvement in mathematics learning outcomes compared to both conventional learning and conventional learning combined with Photomath.

3.3. Results of the Analysis of Students' Interest in Learning

Students' interest in learning was analyzed based on questionnaire scores administered after the treatment in each research group. The results of the descriptive analysis are shown in Table 7.

Table 7
Average Learning Interest Scores

Group	Mean	N	Standard Deviation
Experimental	30.33	30	3.18
Combination	26.97	30	3.30
Control	23.13	30	2.92
Total	26.81	90	4.29

Based on Table 7, the experimental group achieved an average learning interest score of 30.33 ± 3.18 , the combination group scored 26.97 ± 3.30 , while the control group achieved an average of 23.13 ± 2.92 . These results indicate that the experimental group has a higher level of learning interest compared to both the combination group and the control group. These findings suggest that the use of the Photomath app in the learning process not only improves students' mathematics learning outcomes but also increases their interest in learning mathematics.

3.4. MANOVA Test Results

A Multivariate Analysis of Variance (MANOVA) test was conducted to determine the effect of using the Photomath app on two dependent variables simultaneously: student learning outcomes and interest in learning. The results of the MANOVA analysis are presented in Table 8.

Table 8
The Results of MANOVA Analysis

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Group	Study Results	778,689	2	389,345	39,611	,000	,987
	Interest in Learning	2348,012	2	1174,006	99,123	,000	,998
a. R Squared = ,477 (Adjusted R Squared = ,465)							
b. R Squared = ,695 (Adjusted R Squared = ,688)							

The learning achievement variable had an F-value of 39.613 with a significance level (Sig.) of 0.000, and the interest in learning variable had an F-value of 99.123 with a significance level (Sig.) of 0.000, according to the analysis results in Table 8. The Photomath app significantly affects both variables at the same time when

the significance value is less than 0.05. Additionally, the treatment had a significant impact on both research variables, as shown by the Partial Eta-Squared values of 0.987 for learning outcomes and 0.998 for interest in learning. Therefore, it can be said that using the Photomath app improves students' learning outcomes and interest in mathematics at the same time.

4. Discussion

4.1. The Effect of Using Photomath on Students' Mathematics Learning Outcomes

The study's findings demonstrate that using the Photomath app significantly enhances students' learning outcomes in mathematics. The experimental group employing Photomath outperformed the combination group and the control group in terms of learning outcomes, according to the One-Way ANOVA and Tukey's post-hoc test results. These results show that Photomath is a more effective learning tool than traditional education for helping students comprehend quadratic equations and functions.

The Photomath app shows the methods to solve issues methodically in addition to the final result, which led to an improvement in learning outcomes. Students can better grasp mathematical ideas by following the solution steps that are provided. Students can also independently review their work, which enables mistakes in the problem-solving process to be found and fixed right away. Compared to only getting the answer, this method aids pupils in developing a deeper conceptual grasp. This finding aligns with research at [12], which states that using Photomath can improve learning outcomes by helping students understand the systematic steps involved in solving problems.

Similar results were also reported by [13], which explains that the use of technology-based learning media can improve the effectiveness of mathematics learning by presenting material in a way that is easier to understand. Also shows that integrating technology into mathematics learning through a Problem-Based Learning model aided by GeoGebra can significantly improve students' mathematical abilities [14]. These findings reinforce the idea that the use of digital technology can enhance the effectiveness of the mathematics learning process.

Students can better understand abstract mathematical ideas by using Photomath, which not only supports conceptual understanding but also offers a more visual and participatory learning experience. These findings are supported by [5], which explains that visual-based learning media can improve students' understanding of mathematical concepts and their logical thinking skills through the presentation of more concrete material. Although Photomath has different characteristics from typical visual media, both share the commonality of helping students visualize the problem-solving process, thereby making mathematical concepts easier to understand. The results of this study are also supported by

[8], which states that Photomath helps students overcome difficulties in solving math problems by presenting easy-to-understand solution steps. Additionally, explains that using Photomath gives students the opportunity to learn various problem-solving strategies, thereby improving their understanding of mathematical concepts [9].

This study analyzed the efficacy of employing Photomath across three learning groups the experimental group, the combination group, and the control group in contrast to the majority of earlier research that solely looked at how Photomath affected learning outcomes. The evidence that full usage of Photomath produces superior learning results than both conventional learning and conventional learning mixed with Photomath is strengthened by this comparison, which offers more thorough information about the degree of effectiveness of utilizing Photomath.

4.2. The Effect of Using Photomath on Students' Interest in Learning

Students' enthusiasm in learning mathematics was found to be significantly impacted by using the Photomath app, in addition to increasing learning outcomes. According to the study's findings, the experimental group scored higher on learning interest than both the combined group and the control group. This suggests that using Photomath makes studying more interesting and increases students' motivation to participate in math classes.

Because Photomath allows students to study on their own by providing instant feedback on the problems they solve, there is an increase in their enthusiasm in learning. When students run into problems, the software can help them figure out how to overcome them without waiting for an explanation from the teacher. This increases students' self-confidence, lessens the idea that math is a challenging subject, and motivates them to engage more fully in class.

The findings of this study support the theory of learning interest proposed by [11], which explains that engaging and meaningful learning experiences can increase students' interest in learning. The results of this study are also consistent with [12], which states that the use of Photomath can increase students' interest in learning mathematics. Additionally, explains that the use of technology in learning can improve the quality of learning interactions and create more engaging learning experiences [15]. These findings are reinforced by [16], which shows that interactive digital learning media can increase student motivation and engagement during the mathematics learning process. As students' attention, interest, and engagement increase during learning, their interest in learning improves, thereby having a positive impact on the learning process.

The results of this study also reinforce the findings of [17-19], which state that interest in learning is one of the key factors influencing students' academic success [20].

However, this study not only demonstrates that students' interest in learning increases after using Photomath but also measures this increase based on four indicators: enjoyment, attention, interest, and active engagement. Thus, this study provides a more detailed picture of changes in students' affective aspects after using Photomath [21-25].

4.3. The Effect of Photomath Use on Learning Outcomes as Viewed from Students' Interest in Learning

Students' learning outcomes and interest in learning are significantly impacted simultaneously by using the Photomath app, according to the MANOVA analysis results. These results imply that using Photomath improves students' cognitive skills as well as the affective components that help them learn mathematics successfully [26-27].

Improvements in these two characteristics are linked, according to science. Students that are highly motivated to study are more likely to actively participate in class, concentrate more on comprehending the subject matter, and finish given tasks. On the other hand, students' self-confidence and motivation in learning also rise when they have a more accessible learning experience with Photomath. Learning outcomes in mathematics improve as a result of this reciprocal interaction, which also increases learning interest.

The findings of this study align with [28], which states that interest in learning is one of the factors influencing student learning success. These results are also supported by [229], which explains that the higher a student's interest in learning, the higher their learning outcomes. Thus, the use of Photomath not only helps students understand mathematical concepts but also enhances their interest in learning, which ultimately contributes to improved learning outcomes [29].

This study's primary contribution is its analytical methodology. In contrast to earlier research, which typically looked at learning outcomes or interest in learning independently, this study used MANOVA to examine the impact of Photomath use on both learning outcomes and interest in learning concurrently, involving three learning groups: the experimental group, the combination group, and the control group. This method strengthens the empirical evidence that Photomath can be an effective alternative learning medium in mathematics education and offers a more complete view of Photomath's impact on students' cognitive and affective components [30].

5. Conclusion

The study's findings support the notion that students' interest in and performance in mathematics are positively impacted by using the Photomath app. When it came to enhancing students' learning outcomes in mathematics, full use of Photomath was found to be more successful than either conventional learning alone or conventional

learning in conjunction with Photomath. Additionally, using Photomath increases students' motivation to study, which has a substantial impact on both cognitive and affective aspects at the same time. These results suggest that incorporating technology-based apps into math classes can be a useful alternative teaching method to improve students' comprehension of mathematical ideas while also raising their level of involvement. By comparing the effectiveness of the three learning groups and using MANOVA to analyze Photomath's simultaneous impact on learning outcomes and interest in learning, this study also advances the field of mathematics learning technology research.

This study has a number of drawbacks, including the fact that it only included 11th graders from one school, had a limited sample size, and took place over four sessions, making it difficult to adequately depict the long-term effects of utilizing Photomath. Additionally, if instructor direction is not balanced with the app's use as a learning tool, students may become dependent on it. As a result, it is advised that future studies use a larger sample size, a wider range of educational levels, and a longer study duration. To obtain a more thorough picture of the efficacy of employing Photomath in mathematics learning, future research might also look at how Photomath affects other characteristics, such as critical thinking abilities, problem-solving abilities, mathematical literacy, or autonomous learning.

6. Recommendations

Based on the research findings, mathematics teachers are advised to utilize the Photomath app as a learning tool that supports conceptual understanding, particularly for topics requiring step-by-step problem-solving, such as quadratic equations and functions. The use of Photomath should be accompanied by teacher guidance so that students do not focus solely on the final answer but also understand the concepts and problem-solving processes correctly. Additionally, schools can encourage the use of educational technology by giving teachers the tools and training they need to successfully use digital learning tools into the teaching of mathematics.

To get a more complete view of Photomath's efficacy, future researchers are advised to carry out trials with a larger sample size, varying educational levels, and a longer intervention time. Future studies could also look into how Photomath affects other factors including creativity, mathematical literacy, critical thinking abilities, problem-solving abilities, and independent learning. In order to contribute more broadly to the advancement of mathematics learning technology, studies might also compare Photomath's efficacy with that of other AI-based apps.

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