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Research Article

Enhancing High School Students Problem Solving Ability in Algebra through Artificial Intelligence Based Learning

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ABSTRACT

This research is an experimental study conducted with a population of PGRI 1 Taman Pemalang High School students. The sample consisted of 11th grade students from the odd semester of 2024/2025, selected using cluster random sampling to determine the experimental and control classes. This study aimed to improve students' problem solving skills in algebra in a school environment, focusing on Artificial Intelligence based learning and student independence. The algebra topics covered included linear equations, quadratic equations, polynomials, and systems of linear equations. This research involved two main variables: Artificial Intelligence (AI) and problem-solving ability in algebra. Data was collected using questionnaires, tests, and documentation methods. Data analysis was conducted using a two way ANOVA with factorial interaction in a 2x2 design, supplemented by the Bonferroni test as a post hoc analysis. The results showed that students exposed to Artificial Intelligence-based learning demonstrated significantly higher problem solving ability in algebra compared to students taught with conventional methods. Additionally, students with high independence exhibited better problem-solving ability compared to those with low independence. These findings suggest an interaction effect between Artificial Intelligence based learning and student independence on problem solving ability in algebra. Specifically, students with high independence who underwent Artificial Intelligence based learning achieved the highest problem solving ability compared to all other interaction types. This emphasizes the positive synergistic effect of Artificial Intelligence based learning and student independence in enhancing problem solving ability in algebra.

Keywords: Artificial Intelligence; Problem Solving; Algebra; Mathematics Education

1. INTRODUCTION

From initial communication with PGRI 1 Taman Pemalang High School, it is known that mathematics education is needed because students face various challenges in understanding and mastering mathematical concepts. These challenges include different levels of understanding, difficulties in understanding abstract concepts, and unequal access to technology among students (Aisyah et al., 2018). It is expected that through the implementation of targeted and integrated mathematics instruction, students' ability to understand difficult mathematical concepts will improve and their ability to use technology as a learning tool will increase (Ansari, 2009; Zakiri et al., 2018). This is expected to overcome the challenges faced by students and improve their academic achievement in mathematics.

An analysis of the mathematics curriculum implemented in high school , as presented by the ministry of education and culture (seaqil, 2022) , emphasizes the importance of technology integration in mathematics learning to improve students' understanding and mastery of concepts. With the help of AI platforms such as Symbolab, students gain access to interactive learning resources, as mentioned by Hapsari and Prastowo (Anjarwati et al., 2022; Naz Makhdum et al., 2023; Oumelaid et al., 2023) , which is an important factor in improving learning outcomes. The results of this activity indicate that training in the use of Symbolab will contribute to a significant increase in the effectiveness of teaching mathematics in vocational schools (Naz Makhdum et al., 2023; Pratiwi & Bekti, 2017) .

Analysis of the mathematics curriculum applied in high school , as stated by the Ministry of Education and Culture (Ambarwati & Kurniasih, 2021) , emphasizes the importance of technology integration in mathematics learning to improve students' understanding and mastery of concepts. With the use of AI platforms such as Symbolab, students can have access to interactive and personalized learning resources, which is mentioned by Sari and Purnomo (Purnomo, 2017; Sari & Tanzimah, 2017) as an important factor in improving problem solving skills in Mathematics.

With these results, it can be stated that Symbolab training is expected to make a significant contribution to improving the effectiveness of mathematics teaching in high school . Through a targeted and integrated approach, the training aims to equip students with the necessary technological skills and enhance their understanding of complex mathematical concepts (Ambarwati & Kurniasih, 2021; Eshaq, 2024; Nakamura, 2016) . The use of innovative learning tools such as Symbolab allows learners to enhance deeper mathematical abilities on interesting mathematical materials supported by clear solutions and structured steps (Cahyadi et al., 2023; Sánchez Paredes & Vargas D'Uniam, 2016) . Thus, it is expected that this training will provide a strong foundation for better mathematics achievement among high school students, as well as prepare them with relevant skills in today's digital era.

Based on the identification of problems at the beginning, this community service activities activity focuses on improving skills in the field of mathematical algebra in mathematics education. This activity can improve skills in the field of mathematical algebra, especially among pgri 1 taman high school students. This activity is a form of practicing the Tri Dharma of higher education, this community service activity has several objectives: (1) using AI in improving the quality of mathematics learning in high school ; (2) evaluating/assessing the learning outcomes of mathematical algebra; and (3) teaching skills in accordance with the development of mathematics/computer technology.

The importance of mathematical communication in presenting justifications implies the use of representations that help students organize their thinking (NTCM, 2000) . Representations can be grouped into internal representation systems (mental representation systems) and external representation systems (semiotic representations). These representations, in mathematical communication, may be of different types, such as spoken or written language; active representations (using simulations and/or manipulative materials); iconic (using more or less structured images such as drawings, schemes, diagrams); and symbolic (symbolic mathematical language) (Arnidha, 2016; Hendriana et al., 2014) . As students progress in their mathematics learning, it is expected that they increasingly use conventional forms of representation rather than non-conventional ones For deep understanding, it is necessary not only to know the representation and use it appropriately but also to be able to know the various representations and be able to move flexibly between them (Pourdavood et al., 2020; Wilkinson et al., 2018) , where Mathematics communication uses Research indicators of connecting, constructing, applying, verifying.

The subject on derivative material is a branch of mathematics that studies differential calculations, which are often considered difficult by some students. Here are some related findings and research as follows: (1) Difficulty Factors: Many studies have tried to identify the factors that make calculus difficult for students. Some of the factors highlighted include lack of understanding in prerequisite concepts, lack of problem-solving skills, and lack of experience in analytical thinking (Kurniawan et al., 2017) , (2) Teaching Methods: Research has examined various teaching methods that are effective in overcoming students' difficulties in learning calculus. Approaches that focus on concept understanding, real-world application, and the use of technology in learning have been shown to have a positive impact, (3) Technology in Learning: The use of technology, such as mathematical computing. Research has also highlighted the importance of technology integration in the calculus curriculum, (4) Active Learning Models: Active learning models, such as project-based approaches or problem-based learning, have been shown to assist students in learning calculus better. In this research, taking derivative material into account is very important such as kinematics, describing the rate of change of a quantity such as acceleration, magnetic field flux, and rate of change of temperature (Brokate, 2020; Kuang, 2020) .

In the initial ability of students there are still students who experience problems when faced with derivative problems. Some of these errors are related to procedural, conceptual and technical. The lack of understanding of the derivative concept is one of the causes of these difficulties. And errors will be associated with a lack of understanding of the material or subject being studied. Errors that occur are not always due to lack of knowledge, but rather because prior knowledge does not fit the context of the problem at hand (Kurniawan et al., 2017). From the errors experienced by students, it appears that students prioritize procedural knowledge over conceptual. The research conducted is to measure mathematical problem solving abilitys by looking at the level of understanding and disclosure of mathematical communication orally and in writing in the learning process where the indicators used are: Connecting, Constructing, and Applying, Verifying.

Learning is done through a process of activities with a language of meaning for various communicating activities, activities in which learners are involved and in which they learn and recognize themselves as learners. Learning mathematics means modifying the existing discourse so as to acquire the properties of the discourse practiced by the mathematical community. Such changes can be achieved by direct addition by expanding vocabulary, by developing new routines or by producing and supporting new narratives. In particular communicating mathematical thinking and reasoning is an important part of developing understanding (Angraini, 2019) . Communicating in writing can be very efficient in developing students' mathematical understanding. It is a process that helps students to understand, to extract meaning, and to develop complex ideas (Viseu & Oliveira, 2012) . Students are expected to be able to present and explain problem solving methods and justify their reasoning and results more clearly, coherently, and progressively in a more formal manner, to themselves or others. This can lead to the development of higher cognitive functions, including critical thinking, sound reasoning, and problem solving (Ambarwati & Kurniasih, 2021) . Justification is an important component of learners' mathematical communication. The types of justifications learners present can provide information about their understanding. However, students seem to be very concerned with producing correct solutions rather than with justifying their solutions. Previously (Kurniawan et al., 2017) .

Mathematical Communication presents justifications implying the use of representations (Angraini, 2019) , where representations can be grouped into internal representation systems (mental representation systems) and external representation systems (semiotic representations). These representations, in mathematical communication, may be of different types, such as spoken or written language; active representations (using simulations and/or manipulative materials); iconic (using more or less structured images such as drawings, schemes, diagrams); and symbolic (symbolic mathematical language) (Arnidha, 2016) . As students progress in their learning of mathematics, it is expected that they increasingly use conventional forms of representation rather than non-conventional ones For deep understanding, it is necessary not only to know the representations and use them appropriately but also to be able to know a variety of representations and be able to move flexibly between them. Different types of writing can occur in the mathematics classroom, including expository writing, which is often concerned with how to perform mathematical procedures or to explain why certain mathematical results occur. They concluded that task goal statements are usually presented by learners, whereas justifications are presented in smaller numbers, revealing a limited expository writing style and a limited perspective on what it means to do mathematics.

In the opinion of (Purnomo, 2017) independent learning is defined as learning where learners can increase independence and confidence and independent learning becomes a more satisfying learning experience, compared to more traditional types of teaching strategies. Meanwhile, independent learning is a skill or skill that must be familiarized at university, because habituation in independent learning can help optimize their abilities and maximize their learning outcomes. For self-learning to be optimal, there must be good self-management. Self-management is defined as the ability to work and learn independently, and take responsibility for personal actions (Rachmayani, 2014) . The concept of independent learning according to (Rachmayani, 2014) . Attitudes and behaviors that do not depend on others are measured based on aspects of the existence of initiative from oneself with full confidence. While attitudes and behaviors using all energy and thoughts are measured based on the strength of students during learning until they can do the task. The strength of this attitude and behavior is driven by the strength from within himself in the form of independence to learn and a sense of responsibility for the tasks assigned as a student. Furthermore, attitudes and behaviors related to time so that all tasks imposed on themselves can be completed properly and optimally, high aspects of discipline are needed (Sundayana, 2018) .

State of the Art in research is, that from several definitions that have been listed, so that it narrows down that a learning that is currently needed is one that makes related matters discussed an influence on mathematical math problem solving abilitys. Then Novelty in this study is a learning base with artificial intelligence indicators that pay attention to communication indicators of Mathematics by considering the level of independence.

2. RESEARCH METHOD

The research conducted aims to gain an understanding of the differences in artificial intelligence -based learning in terms of the level of independence in mathematics problem solving abilitys and when there are differences, which is the best that can be used in the learning process of Mathematics. The type of research used is a type of experimental research, by comparing the effectiveness of artificial intelligence -based Mathematics learning with conventional learning processes, where the learning is reviewed with the level of independence on improving Mathematics problem solving abilitys in the subject of Mathematics derived material. The research design carried out is described in the Research design (**Table 1**).

Table 1. Research design

Learning Method (P) Independence Level (K)	Artificial intelligence-based learning P1)	Conventional learning (P2)
High Independence (K1)	P1K1	P2K1
Low Independence (K2)	P1K2	P2K2

This research activity takes research data with the research method used, namely tests where this instrument is to determine the level of student understanding in the learning process that has been carried out. At the stage of taking the test contains a systematic procedure with a clear description. And this test is used to analyze mathematical problem solving abilitys.

Research activities begin with an equality test of research subjects to determine the level of independence in each class consisting of test, control and experimental classes. With the population of SMA Negeri 1 Comal Odd Semester of the 2023/2024 academic year. Then from the test results with a significant level, Ho is accepted if -t$(1-\frac{\alpha}{2}, dk)$ ≤ thitung ≤ t$(1-\frac{\alpha}{2}, dk)$, andα is = 5% and dk = (n1 + n2) - 2. Which means the experimental class is equivalent to the control class. From the calculation of thitung = 1.71 and the value of∝ equal to 5% with t table$(1-\frac{\alpha}{2}, dk)$ = 1.71. So that -1.96 ≤ thitung ≤ 1.96, so it can be concluded that the 2 classes, namely the control and experimental classes, have commensurate and equal levels. Then the next step with the Hypothesis Test as follows:

Hypothesis testing on problem solving abilitys Anova for Two-Way Classification with Interaction. This research uses hypothesis testing, namely the analysis of variation test for two-way classification with interaction, namely analysis of variation with interaction 2 x 2 factorial design.

Table 2. Anova for Two-Way Classification with Interaction 2 x 2 Factorial Design

Sum. Diversity	(JK)	(dk)	(RK)	fcount
Center value of row	JKB	r-1	$S(1)^2 = \frac{JKB}{r-1}$	$f1 = \frac{S_1^2}{S_4^2}$
Center value of the column	JKK	c-1	$S(2)^2 = \frac{JKK}{c-1}$	$f2 = \frac{S_2^2}{S_4^2}$
Interaction	JK(BK)	(r-1) (c-1)	$S(3)^2 = \frac{JK(BK)}{(r-1)(c-1)}$	$f3 = \frac{S_3^2}{S_4^2}$
Error	JKG	rc(n-1)	$S(4)^2 = \frac{JKG}{rc(n-1)}$	
Total	JKT	rcn-1		

Description:

JKT $=\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(x_{ijk} - \bar{x}_{...})^2$ = total sum of squares

JKB $=cn \sum_{i=1}^{r}(\bar{x}_{i...} - \bar{x}_{...})^2$ = the sum of squares for the row center values.

JKK $= rn \sum_{j=1}^{c}(\bar{x}_{j...} - \bar{x}_{...})^2$

JK(BK) $= n \sum_{i=1}^{r}\sum_{j=1}^{c}(\bar{x}_{ij.} - \bar{x}_{i..} - \bar{x}_{.j.} + \bar{x}_{....})^2$

JKG $=\sum_{i=1}^{r}\sum_{j=1}^{c}\sum_{k=1}^{n}(x_{ijk} - \bar{x}_{ij.})^2$ = sum of squared errors

(Walpole, 1995)

The three hypotheses are:

a. H0 : $A_1 = A_2 = 0$
   Ha : $A_1 \neq A_2$

b. H0 : $B_1 = B_2 = 0$
   Ha : $B_1 \neq B_2$

c. H0 : $(AB)_{ij} = 0$
   Ha: $(AB)_{ij} \neq 0$

Benferoni test

In the variant results analyzed if there is an average difference in the level of Mathematics communication from 4 treatments, the next analysis is to use the Benferoni test knowing that the number of samples in each treatment is not the same. The method used is expected to be able to find out the average comparison of Mathematics problem solving abilitys in all treatments in this research,

With the following steps:

1. Identifying H_0 and Ha

   H_0: there is no difference in the mean math problem solving abilitys between the two treatments.

   Ha: there is a difference

2. Testing

   a. Determining the difference in the mean value of Mathematics problem solving abilitys in the predetermined treatment with absolute value.

   b. Calculating the magnitude of SE

$$SE = \sqrt{D\left(\frac{1}{n_A} + \frac{1}{n_B}\right)}$$

   c. Calculate the S value with the formula:

$$S = \frac{\bar{X}_A - \bar{X}_B}{SE}$$

Comparing the price of S with B with $\alpha = 5\%$ and draw conclusions with the criteria if $S \geq B = t_{\left(n-k;\frac{\alpha}{2q}\right)}$ then H_0 is rejected (Walpole, 1995) .

3. RESULTS AND DISCUSSION

At the discussion stage when the sample has a good distribution (normal) and homogeneous, the next step is to test with 2-way anova with interaction to determine the difference in the level of Mathematics problem solving abilitys in students with different levels of independence and in the learning process, the learning process focuses on derivative material, the results can be seen in **Table 3**.

Table 3. Anova for Two-Way Classification with Interaction 2 X 2 Factorial Design

SK	JK	DK	(RK)	F count	Decision
Center Row Value	8728,14	1	8938,14	100,3583	H0 is rejected
Column Center Value	2310,39	1	2320,40	27,2393	H0 is rejected
Interaction	2502,71	1	2502,72	26,4127	H0 is rejected
Error	12742,27	156	87,085		
Total	26482,53	159			

From the analysis of variance table for two-way classification with interaction 2x2 factorial design obtained :

a. F1 = 100.3583 > Ftable = 4.07

   Fcalculated > Ftable, then H0 is rejected

   This means that the level of Mathematics problem solving abilitys in different learning processes is different.

b. F2 = 27.2393 > Ftable = 4.07

   Fcalculated > Ftable, then H0 is rejected

   This means that there are differences in Mathematics problem solving abilitys in students who have different independence, in this case, high and low levels of independence.

c. F3 = 26.4127 > Ftable = 4.07

Fcalculated > Ftable, then H0 is rejected

This means that there is an interaction in the comparison of the type of learning model with independence and the level of mathematical problem solving abilitys.

After being tested using the 2 x 2 anova, the data results were tested again using the Benferoni determinant test. The calculation of the Berferoni test can be described in **Table 4**.

Table 4. Benferoni Test Results

No.	Interaction	Different	S	B	Description
1.	1 - 2	0,32	0,146	1,96	There is no significant difference
2.	1 - 3	7,04	3,34	1,96	There is a significant difference
3.	1 - 4	22,55	10,73	1,96	There is a significant difference
4.	2 - 3	7,35	3,495	1,96	There is a significant difference
5.	2 - 4	22,85	10,885	1,96	There is a significant difference (significant)
6.	3 - 4	15,52	7,388	1,96	There is a significant difference (significant)

Description:

a) treatment 1 (artificial intelligence PB for students with high Independence).

b) treatment 2 (artificial intelligence PB for students with low levels of independence).

c) treatment 3 (Conventional Learning with high level of independence).

d) treatment 4 (Conventional Learning with low level of independence).

In terms of student cooperation, especially in the artificial intelligence -based learning model, there are some students who still cannot understand this learning system, for example, there are some students who work alone and without cooperating with group members in a team that has been formed. And the obstacle obtained from the Conventional learning model is that many students do not listen to the teacher's explanation when the teaching and learning process is taking place (Rachmawati & Listiani, 2022) .In terms of facilities and infrastructure obtained by researchers, there is still a lack of information sources for students, for example reading sources or guidebooks that only rely on modules so that their thinking skills are less broad because information about certain subject matter in this case is derivative material. Based on this discussion, the research results can be summarized as follows: (1) students treated with artificial intelligence -based learning have higher problem solving abilitys than students with conventional methods, (2) students with high levels of independence have higher problem solving abilitys than students with low levels of independence, so there is an effect of independence with learning methods applied to mathematical problem solving abilitys, (3) students who have a high level of independence and get treated with an learning process have the highest level of problem solving abilitys compared to the combination of learning interactions in this research.

4. CONCLUSION

Self The implementation of this research is in the form of training in the use of Symbolab, an AI-based platform, in learning algebraic mathematics at PGRI 1 Taman High School. Assessment and evaluation results showed that the use of Symbolab significantly improved students' understanding of compound math concepts. Students' algebra skills, which were at 40% at the beginning of the training, increased significantly to 83% after the training. These results were presented to the subject teachers as a reference for further provision of mathematics materials by optimizing the use of different media. We are confident that these materials will facilitate the teaching and learning process in the classroom. In addition, it is possible to introduce web-based media or other online media tailored to the conditions and needs of students. This training will not only improve students' understanding of complex mathematical concepts, but also enhance their ability to use technology as a learning tool. As a result, better academic performance in mathematics can be achieved. From the research, the following conclusions were drawn:

1. Students treated with artificial intelligence -based learning have higher problem solving abilitys than students treated with conventional methods.
2. Students with a high level of independence have higher problem solving abilitys than students with a low level of independence, so there is an effect of independence with the learning method applied on mathematical problem solving abilitys.
3. Students who have a high level of independence and are treated with an learning process have the highest level of problem solving abilitys compared to the combination of learning interactions in this research.

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AUTHOR'S CONTRIBUTIONS

The authors discussed the research results and contributed from the beginning to the finalization of the manuscript.

CONFLICT OF INTEREST

No conflicts of interest related to this article have been declared by the authors.

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