

The impact of ChatGPT integration on students' conceptual understanding of polynomials in Mathematics learning

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ABSTRACT

This study investigates the impact of using ChatGPT on students' ability to understand mathematical concepts in polynomial topics. As technology rapidly advances, integrating artificial intelligence into mathematics education is becoming increasingly relevant. This research adopts a quantitative approach with a pre-experimental design, employing a one-group pretest-posttest model. The study involved 28 students from class XI-A at SMA Muhammadiyah 1 Sleman, selected through a non-probability sampling method. The research utilized questionnaires and conceptual understanding tests, both of which were validated for reliability and accuracy using SPSS-25. The findings revealed that incorporating ChatGPT in learning contributed 10.4% to enhancing students' conceptual understanding, with the results of the linear regression test indicating a positive and significant relationship ($p = 0.045 < 0.05$). A comparative analysis of pretest and posttest scores demonstrated an improvement in students' conceptual comprehension following the intervention. These results suggest that ChatGPT can serve as an innovative tool in mathematics instruction, aiding students in developing a deeper understanding of mathematical concepts. The study's implications are expected to offer valuable insights for educators in designing more effective learning strategies and provide recommendations for educational technology developers to enhance AI-based learning features.

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1. Introduction

Conceptual understanding of mathematics is a fundamental aspect of learning at the high school level (Herawati & Sidik, 2023). One of the topics that often poses a challenge for students is polynomials (Monrat et al., 2022; Pleština et al., 2025). This topic encompasses various concepts, including algebraic operations, factorization, and the application of theorems in problem-solving (Ekamornaroon et al., 2024). Difficulties in understanding polynomial concepts can hinder students' comprehension of more advanced topics, such as functions and quadratic equations (Baez et al., 2024). Therefore, innovative and effective teaching strategies are needed to enhance students' conceptual understanding of mathematics, one of which involves utilizing artificial intelligence-based technology such as ChatGPT.

Previous studies have also shown that many students struggle to understand the basic concepts of polynomials due to their weak ability to connect algebraic forms with graphical representations and real-world problem contexts. According to research conducted by (Andriani et al., 2024; Nurhayati & Ni'mah, 2024), most students tend to memorize formulas without understanding the meaning behind

polynomial operations and properties, leading to confusion when faced with different types of problems. In addition, teachers still predominantly use lecture-based methods and routine exercises that lack active interaction and the use of instructional technology (Sufiani et al., 2026). These findings reinforce the urgency of implementing digitally innovative teaching strategies, such as the use of artificial intelligence (AI), to facilitate conceptual understanding and provide adaptive feedback according to students' ability levels.

With advancements in technology, various AI-based applications are increasingly being used in education (Gill et al., 2024). One such application that can be applied in mathematics learning is ChatGPT (Jia et al., 2024). This application is designed to understand context and provide relevant responses based on user input. In learning polynomials, ChatGPT can help students grasp concepts more interactively (Shloul et al., 2024). Moreover, this application is capable of explaining solution steps and directly answering questions related to the subject matter (Einarsson et al., 2024).

The use of ChatGPT in polynomial learning offers various benefits for students (Albahra et al., 2023). First, the application can provide explanations tailored to students' levels of understanding (Jahani Yekta, 2024). If a student struggles to comprehend polynomial factorization, ChatGPT can offer additional examples, step-by-step illustrations, and analogies that are easier to understand. Second, the application serves as an assistive tool for solving exercises and provides immediate feedback on students' answers (Wang et al., 2025). As a result, students can learn independently and gain a better understanding of their mistakes when solving problems.

However, the use of ChatGPT in polynomial learning also presents certain challenges. One such challenge is the possibility that students may become overly reliant on the application to complete problems without genuinely understanding the underlying concepts (Baig & Yadegaridehkordi, 2024). Without the appropriate instructional strategy, students may merely follow the steps provided by ChatGPT without developing the necessary cognitive processes required for mathematical problem-solving (Elim, 2024). Therefore, teachers must guide the integration of ChatGPT to ensure that it supports the development of students' critical and analytical thinking skills (Vázquez-Cano et al., 2023). With a balanced approach, this technology can serve as an effective learning aid without diminishing the role of teachers in facilitating student comprehension (Patac & Patac, 2025).

Additionally, another crucial factor to consider is how teachers direct the use of ChatGPT in mathematics learning (Mhlanga, 2023). Teachers act as facilitators, not only introducing this technology but also teaching students how to utilize it optimally (Tarso et al., 2025). Teachers can assign tasks that require students to actively engage with ChatGPT, such as formulating questions related to polynomial concepts. Furthermore, students can independently construct problem-solving approaches based on the application's guidance and evaluate the accuracy of ChatGPT's responses (Apriwulan et al., 2025; Pulungan et al., 2024). In this way, students do not solely depend on technology but continue to develop their logical and analytical thinking abilities.

Based on the discussion above, this study holds significant value in the development of modern and relevant mathematics teaching methods. By understanding the benefits and challenges of using ChatGPT in polynomial learning, this research is expected to serve as a reference for teachers in designing effective instructional strategies. Additionally, the study can provide insights for students on how to wisely utilize technology in their learning process. For educational technology developers, the findings of this study can serve as a foundation for improving features that better support mathematics learning. Consequently, ChatGPT can be optimally utilized as an innovative learning tool that enhances students' cognitive skills in understanding mathematical concepts.

2. Method

2.1. Research design

This study used a quantitative approach with a pre-experimental design to test the effect of using the ChatGPT application on students' understanding of mathematical concepts in polynomials. The design used was a one-group pretest-posttest design, in which one group of subjects was given a test before (pretest) and after (posttest) the learning intervention using ChatGPT. This design allowed researchers to observe changes that occurred after the treatment in a natural classroom context without full subject randomization.

2.2. Participants

Participants in this study were 28 students of grade XI-A at SMA Muhammadiyah 1 Sleman. The sample was selected using a non-probability sampling technique, considering ease of access and the availability of research subjects. This class was chosen because the students already have experience using digital media in learning, thus supporting the optimal implementation of ChatGPT-based interventions.

2.3. Data collection tools

Data collection in this study used two types of instruments, namely a questionnaire and a conceptual understanding test. The questionnaire consisted of 10 questions used to measure students' perceptions of ChatGPT-based learning. Meanwhile, the conceptual understanding test consisted of 7 questions designed to measure students' mathematical conceptual understanding abilities before and after the intervention. The conceptual understanding indicators used refer to Jihad and Haris (2010), which include the ability to restate concepts, classify objects according to certain properties, provide examples and non-examples, present concepts in various mathematical representations, develop necessary or sufficient conditions for a concept, use and select certain procedures, and apply concepts or algorithms in problem solving.

2.4. Research procedures

The research was conducted in several stages. The first stage was preparation, which included the development and validation of research instruments. The second stage was a pretest to determine students' initial abilities. The third stage was the provision of treatment, which involved learning using ChatGPT, conducted over several sessions. Afterward, students were given a questionnaire to determine their perceptions of the learning process. The final stage was a posttest to measure improvements in students' understanding of mathematical concepts after the intervention.

2.5. Data analysis techniques

The data obtained were analyzed using SPSS version 25 software. Data analysis included instrument validity and reliability tests, and normality tests to ensure data distribution. Furthermore, linear regression analysis was used to determine the contribution of ChatGPT use to improving students' understanding of mathematical concepts.

3. Results and Discussion

Before the research began or before collecting pretest and posttest data, a validity test was conducted to ensure that the instrument used could measure the variables accurately. This process aims to ensure that the data collected is in accordance with the research objectives. In this study, validity and reliability tests were conducted using SPSS-25 software. The research instrument was tested on class XII-B students at SMA Muhammadiyah 1 Sleman who had studied the related material. A question is considered valid if the Pearson Correlation coefficient $r_{\text{count}} > r_{\text{table}}$, and is said to be reliable if the Cronbach's Alpha significance value is more than 0.05. The results of the validity and reliability tests shown in Table 1.

Table 1. Instrument test results

ChatGPT Application Usage Questionnaire			Concept Understanding Ability Test		
Items	r_{count}	Sig.	Items	r_{count}	Sig.
1	0.429	0.666	1	0.704	0.774
2	0.539		2	0.651	
3	0.532		3	0.460	
4	0.517		4	0.693	
5	0.433		5	0.613	
6	0.478		6	0.524	
7	0.429		7	0.678	
8	0.539				
9	0.577				
10	0.524				

Referring to Table 1, all questions in the questionnaire and test are declared valid because they have a calculated $r_{\text{count}} > r_{\text{table}}$ (0.374) for each question. The reliability test shows that the questionnaire instrument for the use of the ChatGPT application has a significance value of $0.666 > 0.05$, while the concept understanding ability test instrument obtained a significance value of $0.774 > 0.05$. Therefore, both instruments are considered valid and reliable so that they are suitable for use in this study. This finding emphasizes the importance of validity and reliability in research instruments to obtain valid and accountable data. The use of SPSS-25 software in this analysis also supports the accuracy of the results obtained, as applied in various experimental studies in the field of Education. Before data collection, students first take a pretest, then carry out ChatGPT-assisted learning in class, fill out the questionnaire given, and finally work on the posttest. After the data is collected, a normality test will be carried out, and the results are presented in Table 2.

Table 2. Normality test results

		Unstandardized Residual
N		28
Normal Parameters ^a	Mean	0.0000000
	Std. Deviation	611.82538657
Most Extreme Differences	Absolute	0.114
	Positive	0.094
	Negative	-0.114
Test Statistic		0.114
Asymp. Sig. (2-tailed)		0.200

Based on Table 2, the Asymp. Sig. (2-tailed) value obtained is $0.200 > 0.05$. This shows that the data is normally distributed. Data normality is the main requirement in parametric statistical analysis, as emphasized by (Aprilia et al., 2025; Siswanto, 2025) and (Mawardi et al., 2024), in his research related to statistical methods in social research. Normal data distribution allows the application of linear regression tests to test the relationship between independent and dependent variables more accurately, so that the conclusions drawn can be more valid and unbiased. Furthermore, a linearity test will be carried out. This test aims to determine whether the sample data comes from a population with a similar level of variability. The results of the test can be seen in Table 3.

Table 3. Linearity test results

Concept Understanding * ChatGPT		Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)	6890470.695	12	574205.891	1.964	0.109
	Linearity	1169766.230	1	1169766.230	4.000	0.064
	Deviation from Linearity	5720704.465	11	520064.042	1.779	0.148
Within Groups		4386213.733	15	292414.249		
Total		11276684.429	27			

Based on Table 3, the significance value of Deviation from Linearity obtained is $0.148 > 0.05$. This shows that there is a significant linear relationship. The relationship occurs between the use of ChatGPT and students' mathematical concept understanding ability. Thus, the use of ChatGPT has an effect on students' mathematical concept understanding ability. This finding is supported by research that shows that the use of artificial intelligence-based technology in learning has a positive impact on students' conceptual understanding (Falebita & Kok, 2024; Qurohman, 2024; Siswanto & Susetyawati, 2024). Furthermore, the regression coefficient will be sought. The results of the regression coefficient calculation can be seen in Table 4.

Table 4. Regression coefficients

Model	Unstandardized Coefficients		Standardized Coefficients		T	Sig.
	B	Std. Error	Beta			
1 (Constant)	6449.484	1281.648			5.032	0.000
ChatGPT	-0.592	483	-0.322		-1.735	0.045

Based on Table 4, a significance value of $0.045 < 0.05$ was obtained. This shows that there is a positive and significant relationship. The relationship occurs between the use of ChatGPT and students' mathematical concept understanding ability. In other words, the use of ChatGPT has a large effect on students' mathematical concept understanding ability, as seen in Table 5.

Table 5. Magnitude of influence

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.322	0.104	0.069	623.48025

Based on Table 5, the R Square value obtained is 0.104. This shows that the use of ChatGPT contributes 10.4% to students' mathematical concept understanding ability. Meanwhile, 89.6% is influenced by other factors that were not studied. These results support the findings of previous research by (Godsk & Møller, 2024; Hatmoko et al., 2024; Wahyuni et al., 2024), which found that digital technology in learning plays a role in improving conceptual understanding although other factors such as learning motivation, environment, and teacher teaching methods also play an important role. In addition, the increase in each indicator of students' conceptual understanding ability can be observed from the students' pretest and posttest scores. The results of the score comparison can be seen in Figure 1.

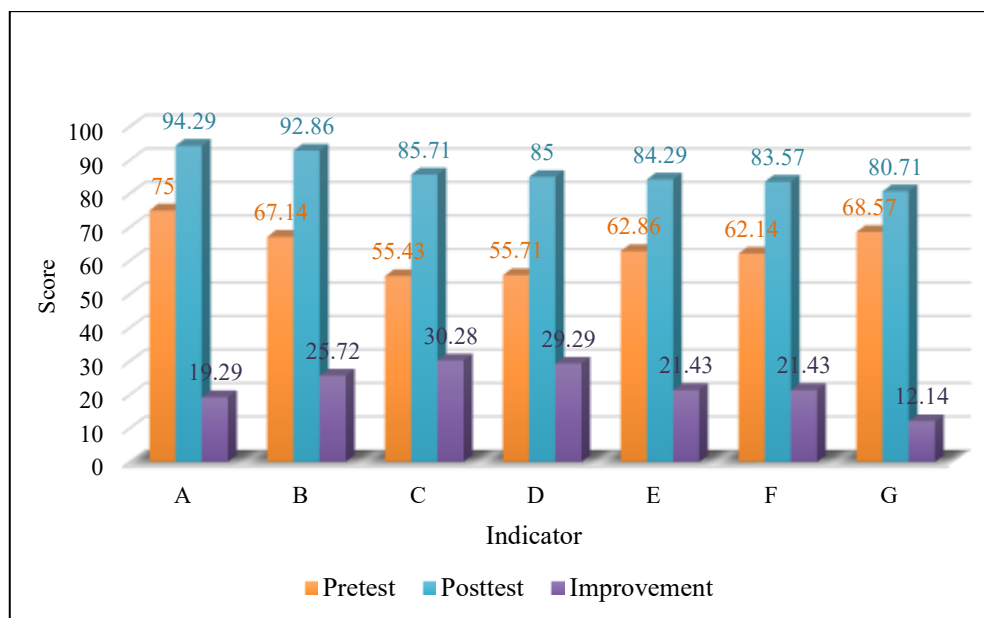


Fig. 1. Improving concept understanding ability

Based on Figure 1, the data on the increase in the mathematical concept understanding indicator shows that the indicator with the highest increase is the indicator of giving examples and non-examples, with a value of 30.28, followed by the indicator of presenting concepts in various forms of mathematical representation, with a value of 29.29. The indicator of classifying objects according to certain properties according to their concepts also shows a fairly high increase, which is 25.72. Meanwhile, the indicator of restating a concept has an increase of 19.29. The indicator of developing necessary or sufficient conditions of a concept and using, utilizing, and choosing certain procedures has the same increase, which is 21.43. On the other hand, the indicator with the lowest increase is applying concepts or logarithms to problem solving, with a value of 12.14. These data show that students' understanding of giving examples and representing mathematical concepts is more developed compared to its application in problem solving.

Overall, the data show that students improve more in understanding and representing concepts than in applying them to solve problems. This means that while students are getting better at recognizing and explaining concepts, they still need support in using them in more complex situations. Therefore, learning activities should place more emphasis on practicing problem-solving to strengthen

their application skills. The results of the increase in achievement of each student in the pretest and posttest as a whole can be seen in Figure 2.

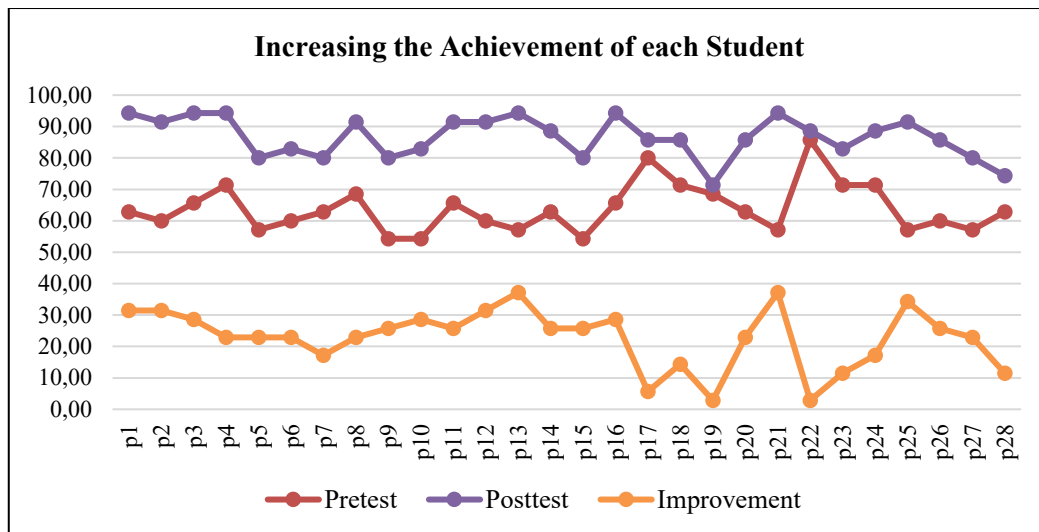


Fig. 2. Increasing the achievement of each student

The results of the descriptive statistical analysis in Figure 2 showed that 28 students participated in this study. In the pretest, participants obtained scores ranging from 54.29 to 85.71, with a total score of 1,788.57 and a mean score of 63.88. Following the intervention, posttest scores increased, ranging from 71.43 to 94.29. The total posttest score reached 2,425.74, with a mean score of 86.63. The improvement in scores ranged from 2.86 to 37.14, with a total gain of 637.14 and an average increase of 22.75. These findings indicate a substantial improvement in students' learning outcomes after the intervention. This result is consistent with previous studies (Anton & Abrahamson, 2025; Freiman & Fellus, 2021), which found that students find it easier to understand concepts through concrete representations before being able to apply them in problem solving. Thus, the use of ChatGPT in learning not only improves general understanding of concepts but also helps students in developing their critical and analytical thinking skills.

The increased scores indicate that the learning intervention in this case, the use of ChatGPT successfully strengthened students' conceptual understanding. Theoretically, this finding is relevant to the concrete-to-abstract representation theory (Bruner, 1973), which explains that students will more easily understand mathematical concepts if the learning process begins with concrete experiences before moving to symbolic or abstract forms. Furthermore, Piaget's constructivist theory also supports these results, where students construct their own knowledge through active interaction with the material and learning environment. Thus, the increased scores not only reflect success in answering questions but also indicate strengthening of conceptual, critical, and analytical thinking processes facilitated by the use of ChatGPT in learning.

The results of this study provide important implications for mathematics learning practices, particularly in the use of artificial intelligence-based technologies such as ChatGPT. The findings indicate that ChatGPT is effective in improving conceptual understanding, particularly in the aspects of representation and exemplification, so teachers can utilize it as a supporting medium to strengthen students' basic understanding. Furthermore, the use of ChatGPT can also encourage independent and interactive learning, where students can explore concepts more flexibly according to their needs. Therefore, the integration of ChatGPT in learning needs to be designed in a targeted manner to not only improve conceptual understanding but also higher-order thinking skills such as problem-solving.

This study has several limitations that should be considered. First, the research design used was a pre-experimental study with a single group and no control group, so the results cannot fully generalize the effects of ChatGPT more broadly. Second, the relatively small sample size, drawn from only one class, also limited the scope of the study's findings. Third, ChatGPT's contribution to improving conceptual understanding was only 10.4%, indicating that many other factors influence student learning outcomes, such as motivation, prior abilities, and teacher learning strategies.

Furthermore, this study did not deeply examine how students' interactions with ChatGPT affect the development of critical thinking and problem-solving skills. Therefore, future research is recommended to use a more robust experimental design, involve a wider sample, and explore other cognitive aspects to obtain a more comprehensive picture.

4. Conclusion

Based on the results of the study, it can be concluded that the use of ChatGPT has a positive and significant effect on students' mathematical concept understanding abilities. Regression analysis shows that ChatGPT contributes 10.4% to improving students' mathematical concept understanding, with other factors not studied contributing 89.6%. Descriptive statistical data shows a significant increase from pretest to posttest scores, with an average increase of 22.75 points. Specifically, the indicators of giving examples and non-examples and presenting concepts in various forms of mathematical representation experienced the greatest increase, while the indicator of applying concepts in problem solving experienced the lowest increase. The implications of this study indicate that the use of artificial intelligence-based technology such as ChatGPT can be an effective tool in mathematics learning, especially in improving students' conceptual understanding. Therefore, teachers can consider integrating ChatGPT into learning strategies to support students' conceptual thinking processes more interactively and adaptively.

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