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APPLICATION OF GEOGEBRA IN ONLINE LEARNING FOR PATTERN RECOGNITION SKILLS IN ANALYTICAL GEOMETRY COURSES

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ABSTRACT

This study aims to analyze the effect of GeoGebra implementation in online learning on students' pattern recognition skills in Analytical Geometry courses. This study used a quantitative method with a quasi-experimental design. Participants were students enrolled in an online Analytical Geometry class. The subjects taken were one class. The instruments used included a pattern recognition ability test consisting of 3 questions and an observation sheet for learning activities. Pattern recognition indicators are recognizing patterns, similarities, and connections. The results showed a significant effect of GeoGebra implementation on students' pattern recognition skills. The effect size calculation results showed a score of 0.99, which is included in the very large category. The overall mean score was 82.47 and the standard deviation was 7.12. The use of GeoGebra effectively helped students visualize abstract geometric concepts. Digital visualization through GeoGebra minimizes inaccuracies that often occur when drawings are created manually, thus enabling students to identify geometric patterns and regularities more clearly. Therefore, integrating GeoGebra into online learning not only improves conceptual understanding but also strengthens students' ability to recognize mathematical patterns in Analytical Geometry.

Penelitian ini bertujuan untuk menganalisis pengaruh implementasi GeoGebra dalam pembelajaran daring terhadap kemampuan pengenalan pola siswa pada mata kuliah Geometri Analitik. Penelitian ini menggunakan metode kuantitatif dengan desain kuasi-eksperimental. Partisipan adalah siswa yang terdaftar dalam kelas Geometri Analitik daring. Subjek yang diambil adalah satu kelas. Instrumen yang digunakan meliputi tes kemampuan pengenalan pola yang terdiri dari 3 pertanyaan dan lembar observasi kegiatan pembelajaran. Indikator pengenalan pola adalah mengenali pola, kesamaan, dan hubungan. Hasil penelitian menunjukkan pengaruh signifikan implementasi GeoGebra terhadap kemampuan pengenalan pola siswa. Hasil perhitungan ukuran efek menunjukkan skor 0,99, yang termasuk dalam kategori sangat besar. Skor rata-rata keseluruhan adalah 82,47 dan standar deviasi adalah 7,12. Penggunaan GeoGebra secara efektif membantu siswa memvisualisasikan konsep geometri abstrak. Visualisasi digital melalui GeoGebra meminimalkan ketidakakuratan yang sering terjadi ketika gambar dibuat secara manual, sehingga memungkinkan siswa untuk mengidentifikasi pola dan keteraturan geometris dengan lebih jelas. Oleh karena itu, mengintegrasikan GeoGebra ke dalam pembelajaran daring tidak hanya meningkatkan pemahaman konseptual tetapi juga memperkuat kemampuan siswa untuk mengenali pola matematika dalam Geometri Analitik.

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INTRODUCTION

Analytical Geometry is an important field of study in mathematics. It bridges the concepts of geometry and algebra. One of the essential skills in mathematics across all fields is Pattern Recognition. This ability is a dimension of Computational Thinking (Fauzi et al., 2025). Pattern recognition enables the understanding of geometric shapes and their algebraic representations. Therefore, this ability supports other higher-level mathematical abilities.

Pattern recognition enables students to identify regularities, structures, and relationships between objects or data, which is crucial for formulating equations, visualizing graphs, and solving complex problems. In the context of mathematics education, pattern recognition is seen as an essential prerequisite for mathematical generalization, which is at the heart of algebraic and analytical thinking (Fauzi et al., 2025) (Shute et al., 2017). It is the ability of students to identify similarities, regularities, or recurring trends in data or problems, both explicitly and implicitly, for the purpose of solving mathematical problems (Rachmi, E. B., Mahendra, I., Purnomo, A., & Budi, 2023).

One of the challenges in learning geometry is visualization. This is especially true since the pandemic shifted learning from full-face to hybrid learning. This challenge is even more acute for geometry, which requires visualization to clarify concepts. Initial observations by researchers revealed that students could solve algebraic problems in geometry. However, when asked to visualize them, they were often inaccurate or even incorrect. Of 10 students asked to draw tangents to circles and sets of circles, only one got even close to correct. This issue has certainly been studied before, and weaknesses in geometric visualization contribute to students' difficulty seeing patterns in geometric sequences (Llinares, 2022).

According to several studies, there are several root causes of students' poor pattern recognition abilities. Students tend to focus on the numbers between the terms in a pattern, forgetting the geometric or algebraic structure of the pattern. Furthermore, it has been stated that students still have difficulty recognizing patterns as functions (Lins, R., & Meira, 2022) (Pinto, G., Peixoto, F., & Leite, 2020). This indicates that students' understanding of patterns is still shallow. Consequently, they face obstacles in pattern recognition.

Addressing this gap requires significant effort. One approach is the use of applications that support geometric visualization capabilities, which can be used in online learning. Technology provides the missing bridge between algebraic and visual representations, effectively enhancing the dynamic visualization capabilities essential for pattern recognition (Zulnaidi, H., & Zakaria, 2022). GeoGebra is a computer-aided system application that helps visualize geometric concepts, even complete with algebraic concepts. GeoGebra is applicative, allowing students to experiment directly. There is a correlation between spatial visualization stimulated through GeoGebra and mathematics learning achievement (Panaoura, A., & Panaoura, 2021). GeoGebra is quite effective in online learning. Previous research even demonstrated the effect of using GeoGebra in online learning on conceptual understanding (Rosmiati, N. N., & Fajariyah, 2023).

Although numerous studies have tested the effectiveness of GeoGebra on mathematics learning outcomes, its specificity in online learning and its relationship to pattern recognition remain unexplored. This study fills this gap by testing a structured online learning model using GeoGebra as the primary tool. Previous research has not addressed the impact of pattern recognition skills using GeoGebra on online learning, particularly in the context of pattern recognition as a coherent component of computational thinking (CT). Research indicates that pattern recognition skills are a crucial component of CT. Pattern identification and observation contribute to the problem-solving process of computational skills (Lehmann, 2024), (Yasin & Nusantara, 2023), and (Polledo et al., 2021).

This study aims to analyze and measure the extent to which GeoGebra applications in online learning can improve students' pattern recognition skills in Analytical Geometry courses. This research is also expected to contribute to the contribution of interactive visual media to geometry learning and its contribution to stimulating mathematical abilities. The implications provide recommendations for geometry instructors regarding the effectiveness of using interactive visual media for visualizing geometric concepts.

METHOD

This qualitative study will provide an in-depth description of how GeoGebra is applied to online learning in an Analytical Geometry course. This method was chosen to provide a deeper understanding of GeoGebra's use in the classroom. It's not just about numbers (Cres & Creswell, n.d.). Pattern recognition ability scores were obtained using a three-item test instrument, with indicators for pattern recognition, similarity, and interrelationship. The test was in essay format. The subjects were 23 Mathematics Education students from PGRI Indraprasta University, taking the Analytical Geometry course. This study was conducted in the odd semester of the 2025/2026 academic year. Subjects were selected using purposive sampling, focusing on students currently taking the analytical geometry course, creating a natural learning environment. Treatments were tailored to their current learning needs. Data analysis techniques used descriptive statistics, including mean scores and standard deviations for pattern recognition ability. The mean score will be calculated overall and per question indicator, as well as the standard deviation.

RESULTS AND DISCUSSION

Result

The The research results will be presented based on statistical and descriptive analyses of the learning activities. The statistical analysis will examine the average maximum and minimum scores obtained by students in general pattern recognition skills. The average student scores for each pattern recognition skill indicator will also be presented. Medians and standard deviations will be analyzed, and effect sizes will be calculated. A descriptive analysis of how online learning with GeoGebra works will also be presented.

3.1 Statistical Analysis

Average Student Score

Students were asked questions to measure their pattern recognition skills using three indicators. This section presents the average scores. The results are presented in Table 2.

Table 1. Average Pattern Recognition Skill Score

Number of Subjects	$\bar{X}$ All indicator	$\bar{X}$ (per indicator)		
		Pattern recognition	Pattern similarity	Pattern relatedness
23	82,47	83.96	80.35	77.30

Based on the information presented in Table 1, the overall average student score was 82.47, with each indicator scoring 83.96 for pattern recognition, 80.35 for similarity, and 77.30 for relatedness. This score indicates that online learning using GeoGebra can still achieve pattern recognition scores above 80. Furthermore, the pattern recognition and similarity indicators also achieved average scores above 80. The relatedness indicator had the lowest average score.

The pattern relatedness indicator also includes the application of patterns to a concept. This may have contributed to the difficulty of the study. It is important that students not only recognize patterns but also relate patterns and generalize patterns to their underlying concepts. Therefore, GeoGebra was used because one of its advantages is its algebraic representation of geometric objects.

The descriptive analysis results showed that students were able to effectively solve pattern recognition problems in Analytical Geometry concepts after using GeoGebra. Interactive visualizations in GeoGebra helped them understand the relationships between geometric elements more accurately and quickly than manual drawing, which often leads to visual errors.

Deviasi Standar

Siswa diberi tes untuk mengukur kemampuan pengenalan pola mereka menggunakan tiga indikator. Bagian ini menyajikan deviasi standar dari skor mereka. Hasilnya disajikan dalam Tabel 1.

Table 2. Deviasi Standar Skor Kemampuan Pengenalan Pola

Number of Subjects	**SD**	**SD (per indicator)**		
		Pengenalan pola	Kesamaan pola	Keterkaitan pola
23	7,12	6,5	7,0	8,0

Based on the information presented in Table 3, the overall Standard Deviation for Pattern Recognition scores for the subject is 7.12. This figure indicates that most students' scores differed by approximately 7 points from the mean score listed in Table 1. This means that most students scored in the range of 75.35 to 89.59. Therefore, most students scored between 75 and 90, which is considered moderate to high. The distribution of the subject scores is moderate, not too broad.

The Standard Deviation for each indicator appears to be approximately equal to the overall score. For the pattern recognition indicator, this means that most students' scores differed by approximately 6.5 points from the mean score listed in Table 1. This means that the subject scores ranged from 77 to 90, not significantly different from the overall Standard Deviation.

Normality was first calculated using the Shapiro-Wilk test. Using statistical analysis tools, the obtained p-value was 0.1915, which is greater than 0.05. Therefore, Ho is accepted, indicating that the data comes from a normal distribution. The following is a histogram forming a normal curve and a Q-Q plot depicting the data distribution converging to the mean line.

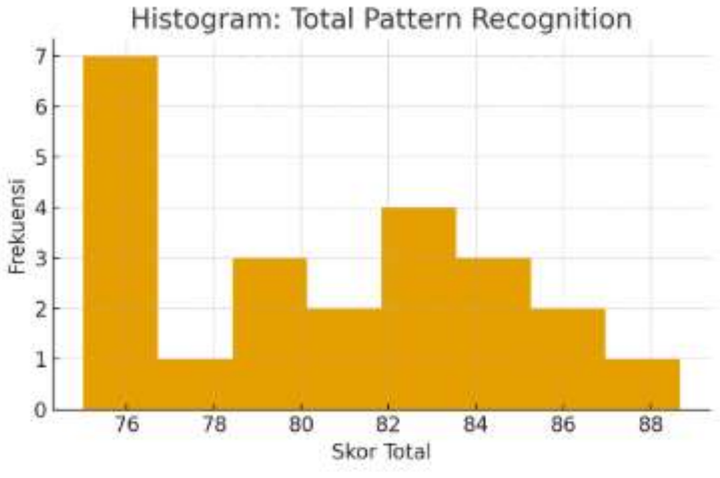


Figure 1. Histogram Normality Test

In the normality test for the total pattern recognition score (mean = 82.47, SD = 7.12, N = 23), the histogram showed a symmetrical distribution shape and resembled a bell curve. There were no long tails or extreme outliers on either side. The distribution of student scores tended to be evenly distributed around the mean, indicating that most students had similar pattern recognition abilities and the data approximated a normal distribution.

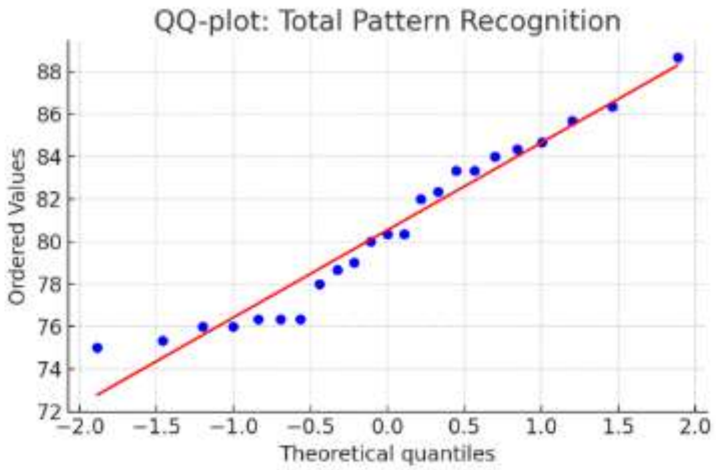


Figure 2. Plot Q-Q Skor Total

Figure 2 shows the points following the diagonal line. Most of the points are very close to the diagonal line, with only slight deviations at the ends (tails). There are no extreme curves at the top or bottom of the graph. The pattern of the points in the Q-Q plot indicates that the distribution of total pattern recognition scores follows a normal distribution. The slight deviations in the tails represent normal variation due to the relatively small sample size (N = 23).

3.2 Learning Description

This course is Analytical Geometry. Online learning using GeoGebra covers the topic of plane equations passing through three points and the distance between points in a three-dimensional plane. Online learning is conducted using the Zoom platform. The learning process involves students learning the general form of plane equations passing through three points and the distance between points in a three-dimensional plane. Students are asked to draw the equations manually, but there are issues with the accuracy and clarity of the visualization. This is due to inaccuracies in the visualization of the three-dimensional plane in a two-dimensional plane. Therefore, to clarify the object, GeoGebra is used. This is shown in the following figure.

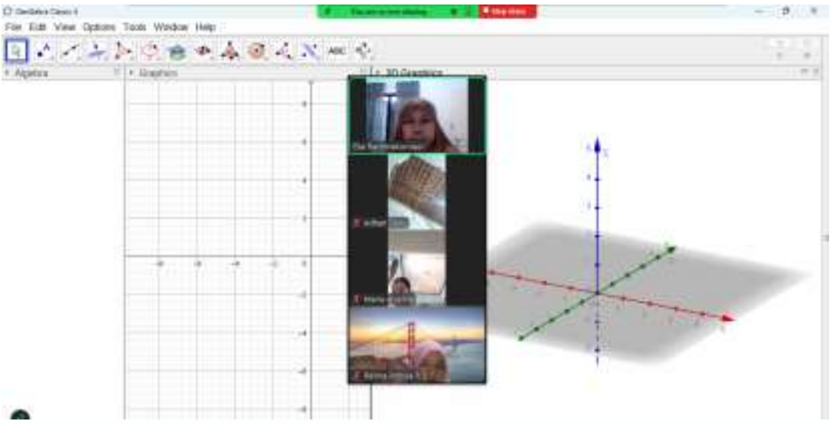


Figure 3. Step 1: Students are presented with a 3D Cartesian plane

In the first step, students are given an initial overview of a three-dimensional Cartesian diagram. This clarifies the positions of the x, y, and z axes.

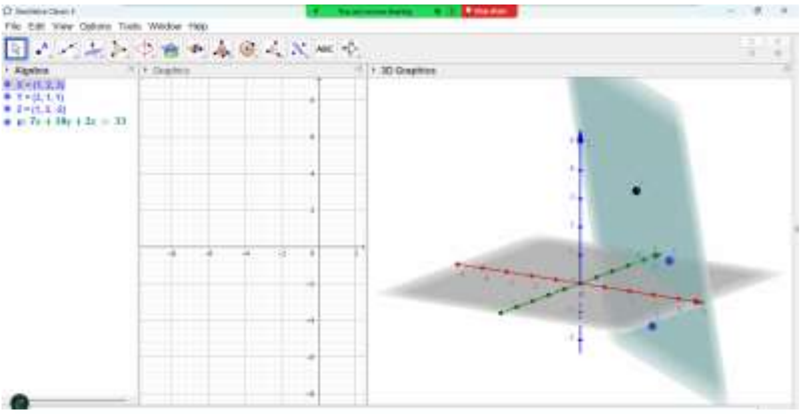


Figure 4. Step 2: Visualizing a plane containing three points

Before finding the equation of a plane through three points, students visualize the positions of the points (x, y, z) and the plane passing through them. The plane clearly shows the positions of the three points on the plane. Then, they proceed with the steps to find the equation of the plane.

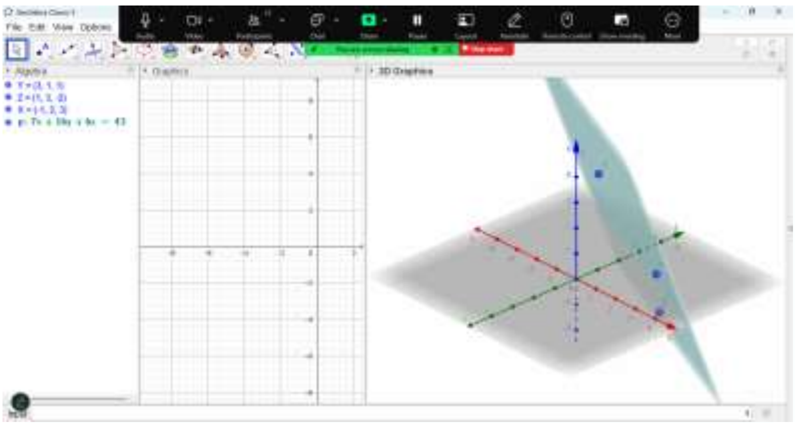


Figure 5. Step 3: The visual is rotated for clearer viewing.

The circled part is an algebraic visualization of the point and plane equation. To see more clearly, the plane is rotated.

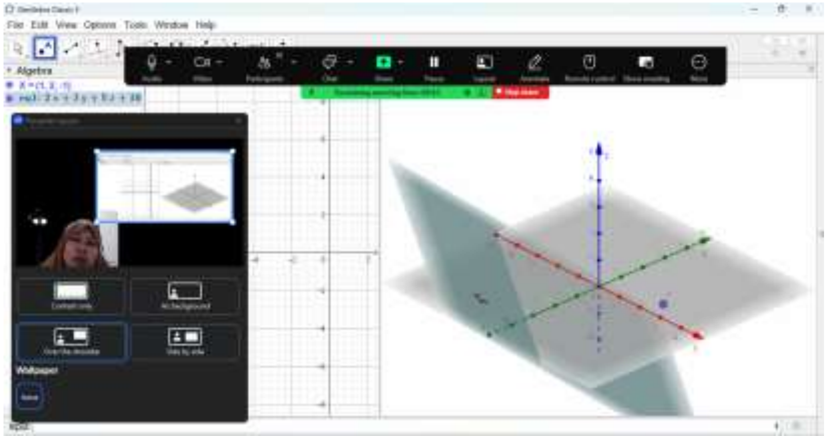


Figure 6. Step 4 Visualizing the distance from a point to a plane

Figure 3-6 shows the steps for displaying a Cartesian diagram of a triangle, constructing a triangle from three points, and finding the triangle's equation. The figure shows a three-dimensional (3D) view using the GeoGebra Classic 5 application. The transparent blue triangle represents the equation 7x + 10y + 2z = 33. The three points (X, Y, Z) are displayed as spherical objects of different colors, each with specific coordinates in 3D space. The three axes (x, y, z) are visualized in different directions and colors (red for the x-axis, green for the y-axis, and blue for the z-axis). This visualization illustrates the relationship of the points' positions to the triangle and can be used to explore whether they are above, below, or below the triangle.

The instrument used to measure pattern recognition was an essay-style test. It consisted of three test questions, each measuring pattern recognition, similarity, and interrelationship. The essay format was chosen to allow for a more in-depth analysis of student responses, beyond simply scoring. The responses from the students, who were the subjects of the study, are presented in the following figure.

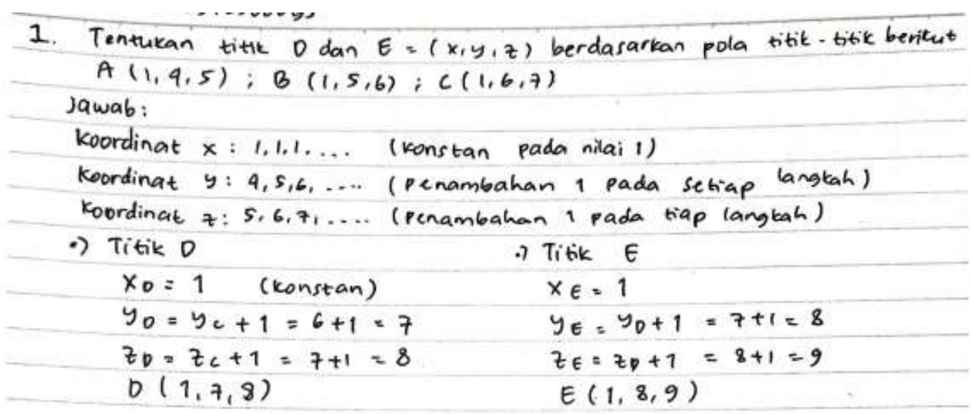
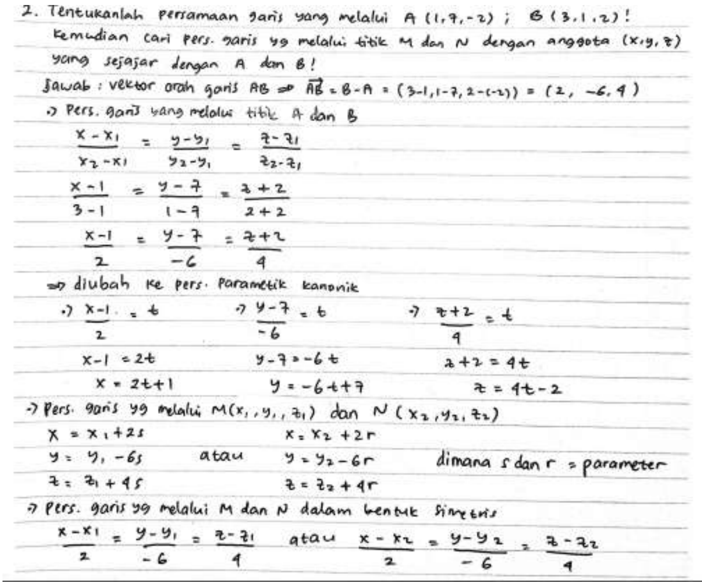


Figure 7. Research subject answers

Pattern recognition is a representation of regularity and summarizes the essential characteristics of each example. The relationships between these patterns are analyzed through mathematical expressions. Figure 7 illustrates the answer to question 1 for the Pattern Recognition indicator. The student was able to recognize the pattern at point (x, y, z) where the x value remains constant at 1, the y value increases by 1, and the z value increases by 1. The student successfully created a general pattern in mathematical form at point D with yo = yc + 1 and zd = zc + 1. Figure 8 below shows the answer to question 2 using the pattern connection indicator.


2. Tentukanlah persamaan garis yang melalui A (1,7,-2) ; B (3,1,2)! Kemudian cari pers. garis yg melalui titik M dan N dengan anggota (x,y,z) yang sejajar dengan A dan B!

Jawab : vektor arah garis AB ⇒ $\vec{AB}$ = B − A = (3−1, 1−7, 2−(−2)) = (2, −6, 4)

→ Pers. garis yang melalui titik A dan B

$\frac{x-x_1}{x_2-x_1} = \frac{y-y_1}{y_2-y_1} = \frac{z-z_1}{z_2-z_1}$

$\frac{x-1}{3-1} = \frac{y-7}{1-7} = \frac{z+2}{2+2}$

$\frac{x-1}{2} = \frac{y-7}{-6} = \frac{z+2}{4}$

⇒ diubah ke pers. parametik kanonik

→ $\frac{x-1}{2} = t$ → $\frac{y-7}{-6} = t$ → $\frac{z+2}{4} = t$

$x-1 = 2t$ $y-7 = -6t$ $z+2 = 4t$

$x = 2t+1$ $y = -6t+7$ $z = 4t-2$

→ Pers. garis yg melalui $M(x_1, y_1, z_1)$ dan $N(x_2, y_2, z_2)$

$x = x_1 + 2s$ $x = x_2 + 2r$

$y = y_1 - 6s$ atau $y = y_2 - 6r$ dimana s dan r = parameter

$z = z_1 + 4s$ $z = z_2 + 4r$

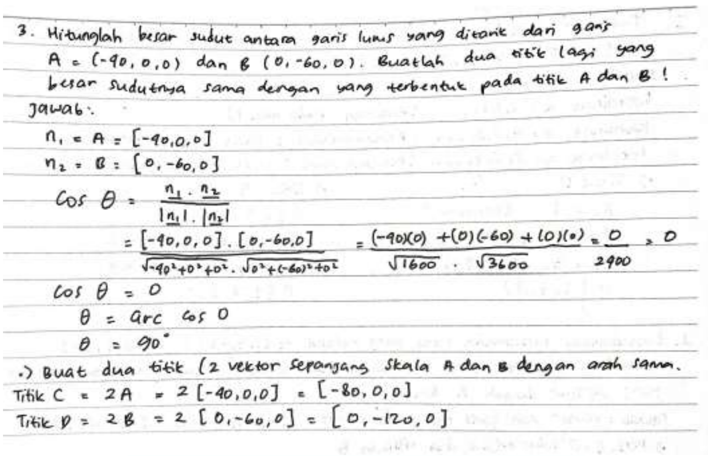
→ Pers. garis yg melalui M dan N dalam bentuk simetris

$\frac{x-x_1}{2} = \frac{y-y_1}{-6} = \frac{z-z_1}{4}$ atau $\frac{x-x_2}{2} = \frac{y-y_2}{-6} = \frac{z-z_2}{4}$

Figure 8. Research subject answers

Pattern association is the ability to identify relationships or connections between elements in a pattern, whether numerical, geometric, or logical, and then generalize them into general rules or principles. In other words, pattern association is not simply seeing that "there's a pattern," but understanding why the pattern forms and how one part relates to another.

The student's answer in Figure 8 clarifies their understanding of the concept. Students should understand how the parallel line pattern works. The relationship between the equation of the first line, and then the subsequent lines, is related to the parallelism of the first line. Unfortunately, in this section, the student did not explain the relationship between the equation of the line passing through A and B and the equation of the line passing through M and N.


3. Hitunglah besar sudut antara garis lurus yang ditarik dari garis A = (−40, 0, 0) dan B (0, −60, 0). Buatlah dua titik lagi yang besar sudutnya sama dengan yang terbentuk pada titik A dan B!

Jawab :

$n_1 = A = [-40, 0, 0]$

$n_2 = B = [0, -60, 0]$

$\cos\theta = \frac{n_1 \cdot n_2}{|n_1| \cdot |n_2|}$

$= \frac{[-40,0,0] \cdot [0,-60,0]}{\sqrt{-40^2+0^2+0^2} \cdot \sqrt{0^2+(-60)^2+0^2}} = \frac{(-40)(0)+(0)(-60)+(0)(0)}{\sqrt{1600} \cdot \sqrt{3600}} = \frac{0}{2400} = 0$

$\cos\theta = 0$

$\theta = \arccos 0$

$\theta = 90°$

→ Buat dua titik (2 vektor sepanjang skala A dan B dengan arah sama.

Titik C = 2A = 2 [−40, 0, 0] = [−80, 0, 0]

Titik D = 2B = 2 [0, −60, 0] = [0, −120, 0]

Figure 9. Research subject answers

Next, Figure 9 is the answer to question 2, which uses pattern similarity as an indicator. Pattern relatedness in pattern recognition refers to the process of recognizing and analyzing relationships or regularities that emerge among data or identified patterns. Pattern relatedness is a crucial aspect of pattern recognition, leveraging the relationships between pattern features to enable efficient and accurate classification, prediction, and recognition.

In Figure 9, students must first identify the relationship between two points A and B through the angle they form. They must then analyze the relationship between two other points with the same angle as points A and B. In the answer above, students are attempting to analyze the relationship between the new points (e.g., C and D) and points A and B, which are multiples of 2. Other answers might involve comparisons or other multiples, such as 3, and so on.

Discussion

Research shows that students understand geometry more easily when visualized. This is despite the fact that students' thinking maturity has essentially reached an abstract level. Pattern recognition results indicate that GeoGebra can indeed influence pattern recognition. Other research suggests that children possess a personal pattern concept in their brains. This means that not all patterns are the same. One study showed that one subject worked by modifying a problem and changing the pattern's color, thus creating their own pattern. This suggests that patterns are not simply understood as "something to be inherited," but as "something that can be created." Furthermore, pattern recognition ability is closely related to problem-solving and arithmetic skills (Ioannis Rizos, 2024).

Pattern recognition is a crucial component of computational thinking skills in mathematics. A systematic literature review indicates that specific studies of the components of computational thinking related to pattern recognition are crucial (Dasgupta & Purzer, 2016). Furthermore, other research suggests the development of software with the primary goal of promoting computational thinking learning, specifically pattern recognition (Barrón-Estrada et al., 2022). Other research has shown that the use of visual programming in geometry fosters critical thinking, particularly in the algorithmic dimension of thinking (Dasgupta & Purzer, 2016). This aligns with the findings of this study, which found GeoGebra effective in visualizing concepts, thus influencing students' pattern recognition abilities. Previous research has revealed why GeoGebra can be used outside of face-to-face classes. According to that study, when students can independently manipulate parameters in GeoGebra and immediately see how these changes affect geometric objects, they gain a powerful mastery experience (Arslan, M., & Zunlu, 2020). GeoGebra's support for hands-on learning can improve academic achievement and self-confidence. Aslan's study, conducted under similar conditions to ours, involved students in an Analytical Geometry course.

CONCLUSION

The results of the study indicate that students' average scores generally performed quite well on pattern recognition questions. The average for each indicator of pattern recognition, pattern similarity, and pattern interrelationship were generally quite good. The standard deviation indicates that students' scores are moderately distributed. The data are normally distributed, indicating that the subjects' pattern recognition abilities are proportionally distributed. The description of learning activities using GeoGebra shows that students are better able to visualize algebra from existing geometric shapes. The recommendation from the results of this study is that in geometry learning, visualization with the help of interactive media is important. One tool that can be used is GeoGebra, considering the advantages of its interactive features and its ability to build geometric and algebraic representations.

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