



An analysis of the difficulty of prospective mathematics teachers on algebraic materials

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Article Information

Submitted Feb 06, 2022

Revised May 15, 2022

Accepted May 31, 2022

Keywords

Difficulty;
Prospective teacher of
mathematics;
Algebraic material;
Straight-line equations.

Abstract

Prospective mathematics teachers experience errors in solving straight-line equations, such as using unorthodox methods, answers that conflict with concepts and wrong calculations. This study aimed to analyze the difficulties of prospective mathematics teachers in algebraic material about straight-line equations. This research is descriptive qualitative research with a case study approach. The subjects in this study were students of the 3rd semester of the Mathematics Education Study Program, Widya Dharma University, Klaten, who had taken field analytic geometry courses. The data collection method in this study used the test method and the interview method. This study uses triangulation techniques to obtain valid data. The triangulation technique used is a triangulation method that compares data or information using different methods. The research instrument includes the main instrument, namely the researcher, whose role is to collect research data and auxiliary instruments in tests and interview guidelines. The data obtained from the interviews were analyzed using the analysis model of Miles, Huberman and Saldana, which includes data condensation, data presentation and drawing conclusions. The results of this study are that prospective mathematics teacher have difficulty in: (1) identifying which equations are straight lines and which ones are not, (2) explaining the concept of gradient, (3) proving the statement that two parallel lines have the same gradient, (4) prove the statement that two lines are perpendicular if the two gradients are multiplied the result is -1, (5) prove the formula for the equation of a straight line with a known gradient and a point through which it passes, and (6) prove the equation for a straight line if two are known the point through which. This study concludes that prospective mathematics teachers have difficulty in the material of straight-line equations.

INTRODUCTION

Junior high school students have difficulty with straight-line material, such as (1) determining the gradient of a known line equation, (2) determining the equation of a straight line if it is known a point and its gradient, and (3) difficulty in understanding the problem, determining what steps to take will be used to solve the problem, and determine the appropriate formula to solve the problem (Tanjung Sari & Soedjoko, 2012; Umam et al., 2017). Students have difficulty determining the location of a point on Cartesian coordinates when solving problems about straight-line equations (Isnaeni et al., 2018; Putra, 2016; Sumarsih, 2016).

Research by Adu et al. (2015) showed that students experienced several errors in solving straight-line equation problems as follows: (1) students did not understand the basic terms used to solve straight-line equation problems; (2) students were unable to translate straight-line equation material story problems; and (3) students were not able to change the content of the story questions to the variables of a straight-line equation. Students also experience conceptual, procedural, and technical errors in solving straight-line equation problems (Kiat, 2005; Novitasari & Fitriani, 2021). When working on description problems on straight-line equation

material, students experience errors, such as errors in reading the questions, misunderstanding the questions, transformation errors, errors in working, and errors in writing the final answer (Putu et al., 2021). Errors made by students when working on questions can cause learning outcomes that have not been maximally achieved (Zahara et al., 2016).

Mastery of teaching materials is one of the abilities that a teacher must possess to meet the demands of professional competence (Utami & Hasanah, 2019; Zulkifli & Royes, 2017). Students do not achieve the desired learning outcomes and have poor learning quality when teachers do not master certain materials (Tuerah, 2015; Zainuddin, 2018). Teachers who do not deliver the material fully and in detail can make it difficult for students to understand the material they convey (Husna et al., 2021; Riadil et al., 2020). Therefore, students of the Mathematics Education Study Program must prepare themselves to fulfill professional competence, especially in mastering mathematics subject matter. The research results by Haryadi and Nurmaningsih (2019) stated that students of the Mathematics Education Study Program as prospective mathematics teachers experienced errors in solving straight-line equations. Prospective mathematics teachers also experience errors in identifying lines and not lines (Udiyono & Yuwono, 2019).

Several relevant studies have been carried out. Haryadi and Nurmaningsih's (2019) research uses three types of errors as a reference to analyze the errors of prospective mathematics teachers in solving straight-line equations. The three types of errors are (1) systematic errors in the form of not giving answers and using deviant methods; (2) random errors in the form of giving answers that are contrary to the concept; and (3) careless errors in writing signs and wrong in the calculation process. The research of Umam et al. (2017), Adu et al. (2015), and Putu et al. (2021) focuses on error analysis in solving problems on straight-line equation material using problem-solving stages such as understanding the problem, determining a plan to solve the problem, implementing a plan to solve the problem, and determining the final answer from the problem-solving process. Some of these studies did not detail identifying and proving statements or formulas on straight-line equations. These aspects include (1) identifying which is a straight line equation and which is not a straight line equation; (2) explaining the concept of gradient; (3) proving the statement that two parallel lines have the same gradient; (4) proving the statement that if two lines are perpendicular to each other when the two gradients are multiplied, the result is -1 , (5) prove the formula for the equation of a straight line with a known gradient and a point through which it passes, and (6) prove the formula for the equation of a straight line if two points pass through it. Based on the description above, it is necessary to research to analyze the difficulties of prospective mathematics teachers in algebraic material about straight-line equations by referring to these six aspects.

METHODS

This research is descriptive qualitative research with a case study approach. The subjects in this study were students in the 3rd semester of the Mathematics Education Study Program at Widya Dharma University, Klaten, who had taken a field analytic geometry course that included straight-line equations. The total number of students who took the field analytic geometry course was eight people. The eight students were used as subjects in this study.

The data collection methods in this study used the test method and the interview method. The test method is used to measure students' ability in the material of straight-line equations by

referring to the following six aspects: (1) identifying which ones are straight-line equations and which ones are not straight-line equations; (2) explaining the concept of gradient; (3) proving the statement that two parallel lines have the same gradient; (4) proving the statement that two perpendicular lines if the two gradients are multiplied is-1, (5) prove the formula for the equation of a straight line with a known gradient and a point through which it passes, and (6) prove the formula for the equation of a straight line if two points pass through it. The interview method was used to obtain in-depth information about the difficulties experienced by students in algebraic material about straight-line equations based on these six aspects by comparing them with the data obtained from the test results.

This study uses triangulation techniques to obtain valid data. The triangulation technique used is a triangulation method that compares data or information using different methods (Denzin, 2015). The research instrument is the main instrument and the auxiliary instrument. The main instrument is the researcher, who collects research data. The research aids were in the form of tests and interview guidelines. The test used is in the form of a descriptive test, consisting of six questions. All test items must represent these six aspects. Validation of the test instrument was carried out by two validators which were experts in geometry. After the tests were carried out for the eight subjects, the test results were analyzed based on the types of answers given. Determination of subjects for interviews is done by selecting students who provide answers with a choice of answer types: (1) wrong strategy, (2) incomplete, or (3) only providing examples for proof questions.

Data obtained from interviews were analyzed using the analysis model of Miles et al., (2014). There are three steps in the analysis model, namely data condensation, data presentation, and drawing conclusions. The results of the interviews were analyzed in the following stages: (1) compiling interview transcripts from the recorded interviews between researchers and research subjects; (2) thoroughly reviewing the interview transcripts; (3) categorizing the types of student difficulties in algebraic material about straight-line equations based on the six aspects studied through data reduction activities; (4) arranging difficulty categorizing units; (5) describing the unit category or type of difficulty; and (6) drawing conclusions.

RESULTS AND DISCUSSION

Based on the analysis of the test answers for the prospective mathematics teacher, three people were selected to be interviewed who were coded S1, S2 and S3. Based on the answers from the test for question number 1, subject S1 mentioned three of the seven equations included in the equation of a straight line, while subject S2 and S3 mentioned five of the seven equations included in the equation of a straight line. Not all research subjects can mention all the equations included in the equation of a straight line. Only one person can name all the equations included in the equation of a straight line. Meanwhile, four people can mention three equations, and three people can mention five equations. Only three people say that $y=0$ is a straight line equation. However, no one says that $x=0$ is not an equation of a straight line. Subject S3's answer to question number 1 is shown in Figure 1.

1. Yang merupakan garis lurus :

A. $y = 2x + 1$

B. $-2x + 5y - 10 = 0$

C. $\frac{1}{3}x + 4 = \frac{1}{7} - 6$

D. $x = -7$

E. $y = 7$

Figure 1. Answers of Subject S3 for Question Number 1

Based on Figure 1, the subject of S3 does not mention that the equations $x=0$ and $y=0$ are straight-line equations. To obtain more in-depth information related to the answer of the doctoral subject, an interview with the doctoral subject was conducted. To reveal more in-depth information related to the doctoral subject's answer to question number 1, an excerpt from the interview between the researcher and the doctoral subject is presented as follows:

- Q : "For question number 1 why did you choose options (a), (b), (c), (d) and (e)? Why are (f) and (g) not?"
- S3 : "The (f) and (g) seem like a point, sir, because $x=0$ and $y=0$. Everything else has value. The value has the slope of the line."
- Q : "For (c) is it a straight line equation?"
- S3 : "Equation of straight line sir. Because it can be multiplied by cross and it can be found the slope value."
- Q : "For (f) and (g), is it a straight line equation?"
- S3 : "That is the point, sir. That's the middle point."
- Q : "Are you sure?"
- S3 : "Yes, because it is right at the intersection of the X-axis and Y-axis, (0,0)."

Based on interviews with subject S1, information was obtained that subject S1 stated that the equation $x=0$ and $y=0$ was not a straight-line equation because there was no point of intersection. Based on interviews with subject S2, information was obtained that subject S2 stated that the equation $x=0$ was not a straight-line equation because it did not contain the y variable. The $y=0$ equation was not a straight line equation because it did not contain the x variable. Based on interviews with subject S3 regarding the answers to question number 1, information was obtained that subject S3 stated that the equations $x=0$ and $y=0$ were a point. The reasons given by the three subjects are not true. Algebraically, subjects S1, S2 and S3 were less careful in observing the two equations. For the equation $x=0$, you can add a variable y with a coefficient of 0. For the equation $y=0$, you can add a variable x with a coefficient of 0. Based on the results of the answers and interviews, it can be said that the subject has difficulties identifying the straight-line equation for the equation. $x=0$ and $y=0$. Errors in giving reasons for the answers submitted indicate that the subject has difficulty delivering answers accompanied by logical reasons (Kereh et al., 2013).

Based on the answers from the test for question number 2, the subjects S1, S2 and S3 were incomplete in explaining. All research subjects are still incomplete in answering question number 2. They only convey the definition of the gradient of a straight line without pictures

and how to find the formula to determine the gradient. Subject S2's answer to question number 2 is shown in Figure 2.

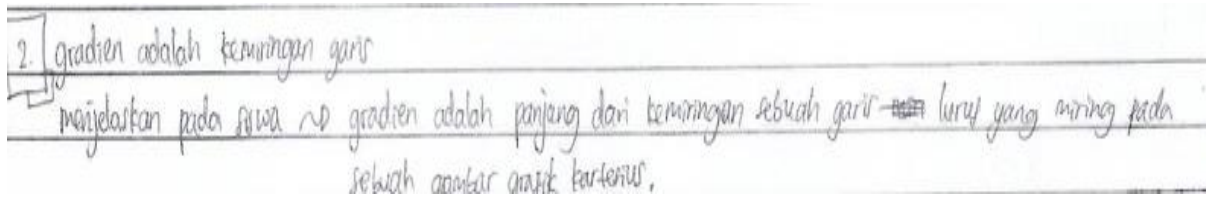


Figure 2. Answers of Subject S2 for Question Number 2

Based on Figure 2, information is obtained that the subject of S2 only mentions the definition of the gradient of a line. To reveal more in-depth information regarding the answer of the master's subject to question number 2, the following excerpts from the interview between the researcher and the subject of the master's degree are presented.

Q : "Can you explain using pictures?"

S2 : "This is a Cartesian diagram. For example, here is a dot $(a, 0)$, here $(0, b)$. This is the line."

Q : "What is the formula for finding the gradient if you know two points on the line."

S2 : " $m = \frac{b}{a}$,"

P : "Why can $\frac{b}{a}$?"

S2 : "Because it is known that b and a "

Q : "Isn't it the best? $\frac{b}{a}$?"

S2 : "No"

Based on the results of interviews with subject S2 related to question number 2, information was obtained that subject S2 said the formula for finding gradients was $m = \frac{b}{a}$ which was obtained from two points, namely $(a, 0)$ and $(0, b)$. However, algebraically the formula he mentioned is wrong. If the two points are known, then the formula is $m = -\frac{b}{a}$. Based on the interviews with subjects S1 and S3, information was obtained that subjects S1 and S3 could not prove the formula for determining the gradient of a straight line. Based on the results of the answers and interviews related to question number 2, it can be said that the subject can only state the definition of the gradient of a straight line but cannot prove the formula for determining the gradient. In other words, the subject has difficulty fully explaining the concept of gradient. Teachers who do not deliver the material fully and in detail can make it difficult for students to understand the material they convey (Husna et al., 2021). Putra (2016)'s research results show that students have difficulty finding formulas for gradient properties from straight-line equations.

Based on the answers from the test for question number 3, subjects S1, S2 and S3 prove that two parallel lines have the same gradient by giving an example. In question number 3, the subject is asked to prove the statement that two parallel lines have the same gradient. One subject did not answer question number 3, one subject answered by only providing a picture of two parallel lines, one subject answered with the wrong strategy, and five subjects answered the question by giving examples. The five subjects give examples of two different straight-line

equations with the same gradient. They then determined the gradient of the two straight-line equations they provided. Figure 3 below shows the answers to the subject of S1 related to question number 3.

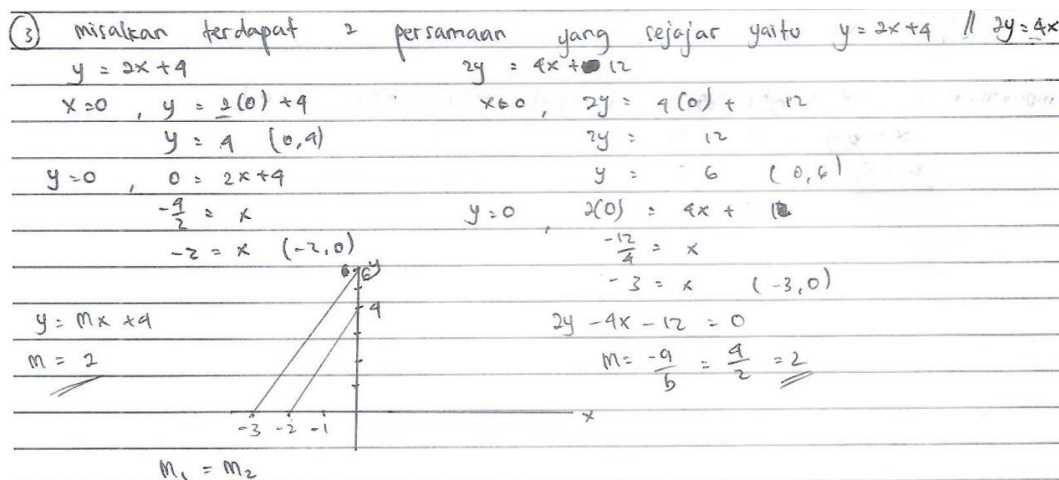


Figure 3. Answers of Subject S1 for Question Number 3

Based on Figure 3, information is obtained that the subject of S1 provides two different examples of straight-line equations. Subject S1 draws a graph of the two equations by first determining the point of intersection with the X-axis and Y-axis. After that, subject S1 determines the gradient of the two equations and shows that the gradient of the two equations is the same. 1. To reveal more in-depth information related to the subject of S1's answer to question number 3, an excerpt from the interview between the researcher and the subject of S1 is presented.

P : "Try to explain your answer to question number 3."

S1 : "From me, let me assume that there is a problem with equation 1 and equation 2. We look for the gradient, and the gradient is the same"

P : "Look at equation 1."

S1 : " $y = 2x + 4$ with gradient 2, whose equation 2 is $2y = 4x + 12$ with gradient 2"

Q : "Why do you come up with the equation $2y = 4x + 12$?"

S1 : "Because at points x and y it's actually just a shift. The points x and y in this second equation are actually twice that of the first equation."

Q : "What about this 12?"

S1 : "It's just a constant; it doesn't affect."

Q : "This constant is not accidentally created twice the first constant?"

S1 : "Intentionally not made the same"

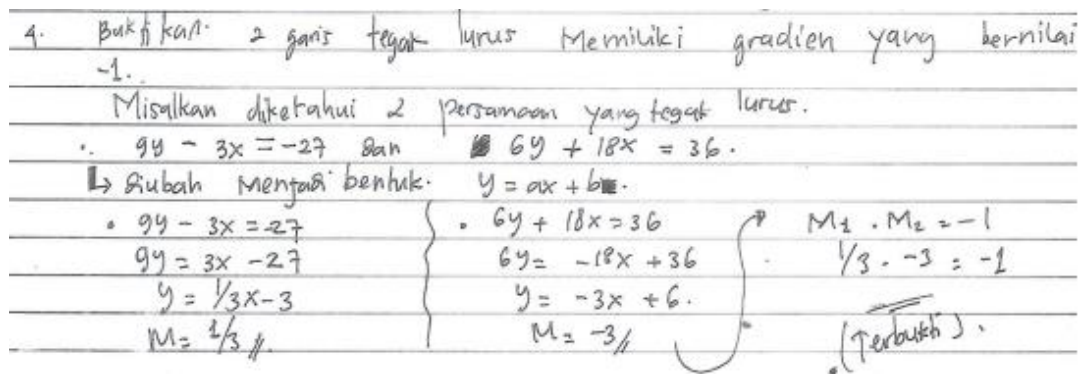
P1 : "Why"

S1 : "Yesterday, I wanted to make it twice, but it turned out to be the same thing. So, what affects it is x and y."

Based on the interview results with subject S1 regarding the answer to question number 3, it was obtained that subject S1 had given an example of two straight-line equations that intentionally made the gradient the same from the start. The coefficients of the variables x and y in the second equation are made twice the coefficients of the variables x and y in the first

equation by making the constants different. Subject S1 was not able to prove the statement algebraically correctly. This is because the subject of S1 does not provide a geometric review first but instead provides an example that shows the statement's validity. Based on the answers of the subject of S1 and the interview results with the subject of S1 regarding question number 3, it can be said that the subject has difficulty proving the statement that two parallel lines have the same gradient.

Based on the answers from the test for question number 4, the subject of S1 did not answer, while the subject of S2 and S3 proved two mutually perpendicular lines, the product of the two gradients was -1 by giving an example. In question number 4, the subject was asked to prove the statement that two The line that is perpendicular to the product of the two gradients is -1. Four subjects did not answer, one subject answered with the wrong strategy, and three subjects answered by giving examples. The three subjects give examples of two different straight-line equations, but the product of the two gradients is -1. They then determined the gradient of the two straight-line equations they provided. Figure 4 below shows the answer to the subject of S3 related to question number 4.



4. Buktikan: 2 garis tegak lurus memiliki gradien yang bernilai -1.

Misalkan diketahui 2 persamaan yang tegak lurus.

• $9y - 3x = -27$ dan $6y + 18x = 36$.

↳ Ubah menjadi bentuk: $y = ax + b$.

• $9y - 3x = -27$
 $9y = 3x - 27$
 $y = \frac{1}{3}x - 3$
 $m = \frac{1}{3}$

• $6y + 18x = 36$
 $6y = -18x + 36$
 $y = -3x + 6$
 $m = -3$

• $m_1 \cdot m_2 = -1$
 $\frac{1}{3} \cdot -3 = -1$
 (Terbukti).

Figure 4. Answers of Subject S3 for question number 4

Based on Figure 4, information is obtained that the subject of S3 proves the statement contained in question number 4 by giving examples of two different equations. In the next step, subject S3 determines the gradient for each equation. In the last step, subject S3 shows that the product of the two gradients is -1. To reveal more in-depth information related to the doctoral subject's answer to question number 4, an excerpt from the interview between the researcher and the doctoral subject is presented.

- Q : "In answering question number 4, you use the same method as number 3, right?"
- S3 : "Yes, the same sir. I don't know how to prove it directly."
- Q : "Why can you give these two equations? What's your reasoning?"
- S3 : "I tried it first. The first equation is arbitrary. First, find the value of m1. Then look for the inverse of this m1. The reciprocal of 1/3 is -3"

Based on the interview results with the doctoral subject regarding the answers to question number 4, information was obtained that the doctoral subject proved the statement contained in question number 4 by giving examples of two different equations. This is because the subject of S3 has not been able to prove it algebraically correctly. The subject of S3 assumes any equation first and determines the gradient at the same time. After that, subject S3 determines

the gradient for the second equation so that the product with the first gradient is -1. The next step is subject S3 to form the second equation, which has the second gradient. Based on the answer of the doctoral subject and the results of the interview with the doctoral subject regarding question number 4, it can be said that the subject has difficulty proving the statement that two lines are perpendicular to the product of the two gradients are -1.

Based on the answers from the test for question number 5, subject S1 proves the formula for determining the equation of a straight line if it is known the gradient and a point it passes by assuming the value $c = 0$, subject S2 proves it by giving an example. In contrast, subject S3 proves the formula correctly. In question number 5, the subject is asked to state the formula to determine the equation of a straight line if it is known that a point (x_1, y_1) is traversed by a straight line and its gradient is m and at the same time is asked to prove the formula. There was only one subject who answered the question correctly. Meanwhile, three subjects did not give an answer, three subjects answered by giving an example, and one answered by assuming $c=0$. Figure 5 below shows the answer of subject S1, who answered by assuming $c = 0$.

5 Rumus $y - y_1 = m(x - x_1)$
 Pembuktian :
 $ax + by + c = 0$ (misalkan $c = 0$)
 $a(x - x_1) + b(y - y_1) + 0 = 0$
 $0 = a(x - x_1) + b(y - y_1)$
 $-b(y - y_1) = a(x - x_1)$
 $y - y_1 = \frac{a}{-b}(x - x_1)$
 $-\frac{a}{b} = m$ (gradien)
 $y - y_1 = m(x - x_1)$
 Terbukti

Figure 5. Answers of Subject S1 for Question Number 5

Based on Figure 5, subject S1 gives an equation $ax+by+c=0$ and assumes $c=0$. Then, subject S1 changes x to $(x-x_1)$ and y to $(y-y_1)$, so subject S1 can find the formula $y-y_1=m(x-x_1)$. The following is an excerpt from the interview between the researcher and subject S1 regarding answering question number 5.

P : "Try to explain the answer to question number 5."

S1 : "The formula is $y-y_1 = m(x-x_1)$."

The proof, using the general equation, $ax+by+c = 0$. Let's say $c = 0$. Then, we can change x in a by $(x-x_1)$ and change y to $y-y_1$. The equation becomes $0 = a(x-x_1)+b(y-y_1)$. Then, both sides are subtracted by $b(y-y_1)$. The result is $-b(y-y_1) = a(x-x_1)$. Divide both sides by $-b$, so we get $y-y_1 = -a/b(x-x_1)$. $-a/b = m$, then $(y-y_1) = m(x-x_1)$ "

Q : "Why can x be changed to $(x-x_1)$?"

S1 : "Because it is a distance."

P : "If the value of c is not made 0, can it be done, sis?"

S1 : "Later c will not be lost in the equation, sir. I have a hard time proving it."

Based on the interview excerpt with the subject S1, information was obtained that the subject S1 gave the reason why the subject S1 changed x to $(x-x_1)$ and y to $(y-y_1)$. If the value of c is not made 0, the subject of S1 has difficulty proving the formula. This shows that the subject of S1 has difficulty proving the formula algebraically. Based on the results of the subject S1's answers and the results of interviews with subject S1, it can be said that the subject has difficulty in proving the equation of a straight line with a known gradient and a point through which it passes.

Based on the answer to question number 6, subject S1 only writes what is known in the problem. Subject S2 proves the formula for determining the straight-line equation if it is known that the two lines are contained in the line by providing examples, while subject S3 proves the formula correctly. In question number 6, the subject is asked to state the formula to determine the equation of a straight line if two points are known and prove the formula. There is only one subject who can answer question number 6 correctly. Meanwhile, three subjects did not answer, one subject answered with the wrong strategy, two subjects only wrote down what was known on the questions, and one student answered by giving examples. Figure 6 below shows the subject's answer to S2 for question number 6, which answers by giving an example.

6. Tentukan persamaan garis yang melalui titik $(-\frac{2}{3}, 14)$ dan $(4, -3)$

Pencapaian :

Formula $\frac{y-y_1}{y_2-y_1} = \frac{x-x_1}{x_2-x_1}$ → substitusi rumus :

$$\frac{y-14}{-3-14} = \frac{x-(-\frac{2}{3})}{4-(-\frac{2}{3})}$$

$$\frac{y-14}{-7} = \frac{x+\frac{2}{3}}{\frac{14}{3}}$$

$$\frac{14}{2}(y-14) = -7(x+\frac{2}{3})$$

$$\frac{14}{2}y - \frac{56}{2} = -7x - \frac{14}{3}$$

$$14y - 56 = -21x - 14$$

$$14y = -21x - 14 + 56$$

$$14y = -21x + 42$$

$$\div 7$$

$$2y = -3x + 6$$

∴ Terbukti

Figure 6. Answers of subject S2 for Question Number 6

Based on Figure 2, information is obtained that the subject of S2 assumes that two points are substituted into the formula to determine the equation of a straight line. After that, the subject S2 tries to prove the formula by writing down the formula at the beginning of the proof. This resulted in the subject S2 having difficulty completing the proving process algebraically. The following is an excerpt from the interview between the researcher and the master's degree subject to obtain more in-depth information on why the master's subject answered that way.

P : "Try to explain your answer to question number 6."

- S2 : "The formula is $y-y_1 = m(x-x_1)$. I will give an example question. Just enter it, then you will find the general form of a straight line."
- P : "It means that you enter the point into the formula, then you find the general form. Then?"
- S2 : "Already"
- P : "What is this one, sis?"
- S2 : "Here, I wanted to prove the formula. But still confused"

Based on the excerpt from the interview with the master's subject, information was obtained that the master's subject tried to prove the formula by giving an example of two points that he took. The subject of S2 also tried to prove the formula succinctly without giving an example, but it was not finished because subject S2 was confused about how to solve it. Based on the results of the subject S2 answer and the results of the interview with the subject S2 related to question number 6, it can be said that the subject has difficulty proving the formula for determining the equation of a straight line if the two points it passes through are known.

The material for straight-line equations is contained in the analytical geometry course (Pasandaran & Patmaniar, 2016). Prospective mathematics teachers often have difficulty studying analytic geometry (Saluza, 2015). Based on the information obtained from the answers and the results of interviews with research subjects, it can be said that the subject still has difficulties in working on proof questions on straight-line equation material. Prospective mathematics teachers have difficulty solving proof problems on analytic geometry material (Junaedi, 2014; Yuwono, 2016) and difficulty determining the reasons for the proof steps (Yazidah, 2017). The difficulties experienced by prospective mathematics teachers in proving to include determining the initial steps of proof and the difficulty of applying concepts and principles in finding formulas (Sundawan et al., 2018). Prospective mathematics teachers often make mistakes in proving a mathematical statement by giving certain examples (Herutomo, 2019). Prospective mathematics teachers consider providing relevant examples to validate the proof (Matitaputty, 2020). This difficulty is caused by a lack of practice working on mathematical proof problems (Sulfiah et al., 2020). Prospective teachers also have difficulty connecting the information they get with the formulas used in solving analytic geometry problems (Pranyata, 2019).

This research implies that there is a finding that prospective mathematics teachers are still having difficulties with straight-line equations related to aspects of identifying and proving statements or formulas on straight-line equations that are following the contents of the student handbook written by As'ari et al. (2017). These findings indicate a difference from the results of research from Umam et al. (2017), Adu et al. (2015), Putu et al. (2021) which focus more on error analysis in solving problems on the material of straight-line equations by using problem-solving stages.

This study has not discussed the solution to the difficulties experienced by prospective teachers in the material of straight-line equations. This solution is expected to be implemented by lecturers to improve the quality of analytical geometry lectures so that students, as prospective teachers, do not experience difficulties with the material. Suggestions that can be given to future research are the need for research to determine the right solution to overcome the difficulties of prospective teachers in the material of straight-line equations.

CONCLUSIONS

The conclusion of this research is that prospective mathematics teachers have difficulty in algebra about straight-line equations in terms of (1) identifying which is a straight line equation and which is not a straight line equation, (2) explaining the concept of gradient, (3) proves the statement that two parallel lines have the same gradient, (4) prove the statement that two perpendicular lines, if the two gradients are multiplied, is -1, (5) prove the formula for the equation of a straight line with a known gradient and a point through which it passes, and (6) prove the formula for the equation of a straight line if two points pass through it.

AUTHOR CONTRIBUTIONS STATEMENT

MRY was the drafter of this research, both in terms of instrument preparation and data collection. SW helps in writing articles.

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