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Students' Errors in Solving Plane Geometry Problems Using E-Learning-based Diagnostic Tests

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Abstract. *During the Covid-19 pandemic, the implementation of online and shift learning systems has been identified as one factor contributing to learning loss in mathematics problem-solving skills specifically in plane geometry problems. The primary objective of this research was to investigate the different types of errors committed by junior high school students in Banda Aceh, Indonesia, in solving plane geometry problems using e-learning diagnostic tests. A descriptive qualitative approach was adopted, and 24 Year 8 students were selected as subjects. The data were collected through tests and interviews, and data analysis involved data reduction, data presentation, data verification, and drawing conclusions. The findings revealed that the percentage of students' errors in solving conceptual problems, principal problems, and verbal problems were 76.39%, 68.75%, and 75%, respectively. Subsequently, the results from the second test and interviews with six students showed that students encountered several conceptual errors, including errors in stating angle symbols, errors in identifying the type of shape provided, errors in deducing information regarding properties, perimeter, and area of plane geometry, lack of knowledge regarding the application of the appropriate plane geometry formula, and inability to solve problems using the correct procedure. Principal errors were related to algebraic operations, while verbal errors involved translating problems and improper application of concepts and principles. The understanding of the types of errors will help teachers detect errors made the students early.*

***Keywords**: diagnostic test, e-learning, students' mathematical errors*

Introduction

One of the fundamental objectives of education at all levels should be to cultivate creative and logical thinking SCills in students to enable them to solve problems effectively (Švecová, Rumanová, & Pavlovicová., 2014). This objective aligns with the educational goals outlined in Permendikbud No. 64 of 2013, stating that students should possess critical, analytical, logical, and meticulous problem-solving SCills with accountability, responsiveness, and perseverance (Permendikbud, 2013). However, the Covid-19 pandemic has introduced a new set of challenges for Indonesia's society and government, particularly in the education sector, making it difficult to realize the goals of education effectively.

The distance learning policy was introduced to ensure continuity of education during the Covid-19 pandemic. However, implementing distance learning has presented various challenges that have impacted the learning process. For instance, the absence of face-to-face interaction between teachers and students and students with their peers has hindered teaching effectiveness. Moreover, inadequate access to necessary technological resources, such as Android devices, reliable network connectivity, and sufficient data credit, has resulted in some students being unable to fully participate in remote learning activities. These limitations have, in turn, led to reduced teaching hours and incomplete assignments, thereby impeding optimal learning outcomes (Jamila, Ahdar, & Natsir., 2021).

Amid the COVID-19 pandemic, schools have implemented a shift learning system during the new normal period of the 2020/2021 school year. This system involves dividing students into two groups and alternating their attendance: the first group attends face-to-face school on the first week, and the second group attends on the second. Alternatively, each group may attend face-to-face school three days a week while the other group studies independently at home with teacher-assigned taSCs (Kairiusta, Nazmi, & Junaidi., 2021). The shift learning system is a response to health protocols recommended by the government: preventing crowds, maintaining distance, wearing maSCs, and practicing frequent hand washing.

The shift learning system implemented during the new normal period for the 2020/2021 school year has negatively impacted the learning process. One of the main issues is that the amount and quality of learning material students receive is not optimal. Due to the shortened time and limited face-to-face interactions, some students struggle to grasp all the information and concepts presented. Furthermore, students assigned to work independently at home might not fully understand the taSC or receive adequate support and guidance from the teacher. Consequently, some students might not complete their assignments to the best of their abilities or copy answers from others, such as their parents, tutors, or peers (Jamila et al., 2021).

Due to the implementation of online and shift learning systems, there is a concern that students may suffer from learning loss, which refers to a situation where students lose knowledge and SCills due to certain conditions, resulting in a decrease in their ability to master competencies that must be achieved (*The Education and Development Forum*, 2020). Bartholo, KoslinSCi, Tymms, and Castro (2022) found evidence of learning loss and increased learning inequality during the Covid-19 pandemic. Engzell, Frey, and Verhagen (2021) and Maulyda, Erfan, and Hidayati (2021) have also concluded that student learning outcomes have declined and learning loss has occurred, particularly in mathematics. Therefore, parents, teachers, school principals, and the education department must provide special attention to this issue.

One of the fundamental components of mathematics is geometry, a branch of mathematics that examines the properties of shapes: points, lines, planes, and space. The geometry curriculum typically covers various topics, including lines and angles, 2-D shapes, 3-D shapes, and transformations. Since the material is taught continuously and hierarchically, students' understanding of the previous material is essential for comprehending the subsequent material (Amelia, 2018).

Several studies have demonstrated that many students have limited geometry mastery and are often prone to making mistakes when working on geometry questions (Biber, Tuna, & Korkmaz., 2021). Previous research has highlighted several reasons for these mistakes, including students' inadequate understanding of the questions, inability to design and develop effective problem-solving strategies, and difficulty identifying the correct answers (Abdullah, Abidin, & Ali, 2015). In addition, students frequently commit errors when applying formulas due to a lack of comprehension of the underlying concepts, attention to detail, and insufficient effort when tackling the given challenges (Solfitri & Roza., 2015).

Junaidi, Hanifah, and Susanta (2021) reported that the majority of errors made by students in geometry problems were the understanding of the problems (41%), followed by errors in reading problems (30%), process SCill errors (20%), errors in writing the final answer (9%), and no errors in problem transformation. Similarly, Rumbatty (2020) reported that students tend to make mistakes in reading and understanding problems, transforming them, processing SCills, and writing conclusions. Hasanah Sukoriyanto and Sulandra (2022) also concluded that the errors made by students in solving geometry problems are diverse.

The research conducted by Utami (2020) has revealed three main types of errors students make: conceptual, principal, and operational. Conceptual errors refer to the student's inability to comprehend the meaning and purpose of the questions and the use of incorrect symbols in mathematics. Principle errors pertain to mistakes in applying the correct formula, while operational errors are related to students' incapability to follow the appropriate calculation or operating rules. Similarly, Nirawati, Darhim., Fatimah, and Juandi (2022) discovered that students make errors when solving geometry problems, including failure to read and comprehend instructions, carelessness, spending too much time on specific problems, guessing answers, and leaving the answer sheet blank.

One useful approach is to use a diagnostic test to identify the errors that students make in their understanding of mathematical material. This type of test is specifically designed to determine the causes of student failure in learning (Miller, Linn, & Gronlud., 2008). Using a diagnostic test, teachers can diagnose the problems or mistakes that students make and plan follow-up efforts to address those specific issues. The results of a diagnostic test can also serve as a reference for designing learning activities tailored to individual students' needs and abilities (Miller et al., 2008).

Diagnostic tests can be administered via e-learning platforms. As defined by Allen (2013), e-learning is a structured learning system that utilizes electronic devices, including deSCtops and Android, to support learning. The advantage of e-learning is that it allows unrestricted access for all users, enabling them to access the platform anytime and anywhere, as long as there is a stable internet connection. Moreover, Maatu, Elberkawi, Aljawarneh, Rashaideh, and Alharbi (2022) highlighted that e-learning is flexible and can effectively solve remote interactions between teachers and students.

Although several studies have been conducted on diagnostic tests to identify student errors in solving plane geometry problems (such as Irzani, 2010; Yusupova & Tokhtasinova, 2022), none have focused on e-learning platforms. Thus, this study aimed to investigate students' errors in solving plane geometry problems through e-learning diagnostic tests. The research problem is formulated as follows: What are the types of students’ errors when solving plane geometry problems using e-learning diagnostic tests?

Method

This study employed a qualitative approach. Qualitative research is a method used to describe, explore, and understand the experiences of individuals or groups related to a particular phenomenon (Creswell, 2014). This is in accordance with the objectives of this study, namely to identify the types of errors that students make while solving plane geometry problems using e-learning diagnostic tests. Therefore, a qualitative descriptive research design was employed for this study. Qualitative research is descriptive-analytic, employing words, narratives, and pictures to interpret data rather than statistical analysis. The data typically used in qualitative research are collected through tests, interviews, and documentation. During data collection, researchers are often involved in observations.

The participants in this study comprised 24 Year 8 students from a junior high school in Banda Aceh, Indonesia. These students had previously studied plane geometry in Year 7 amidst the Covid-19 pandemic. Following the completion of the diagnostic test, the students were classified into three error categories: conceptual, principal, and verbal errors. Moreover, six students from the participant group were selected for in-depth interviews. Those were students who made mistakes in answering questions that were adjusted to the characteristics of the problems it.

The research instrument was in the form of written tests and interviews. The test consisted of multiple-choice items, following the basic competencies of plane geometry content in junior high school. Based on the theory of Köhn and Chiu (2018), diagnostic test questions have the main prerequisite; namely, they must fulfill the requirements of the Q matrix. The Q matrix is satisfactory if it uses a realistic number of items involving attributes, so the test questions were developed based on the attributes of plane geometry problems. The preparation of attributes is considered the Learning Continuum, a process of mastery of the material that students must pass, usually based on Competency Achievement Indicators (GPA), sorted from simple to complex

(Kusaeri, 2012). The attributes in the development of the research test items consisted of the properties of triangles and quadrilaterals, the attributes of the perimeter of the triangles and quadrilaterals, and the attributes of the area of triangles and quadrilaterals. The Q matrix is grouped based on these attributes with the statement that solving the properties only requires mastering the attributes, while solving perimeter and area problems requires mastering the attributes.

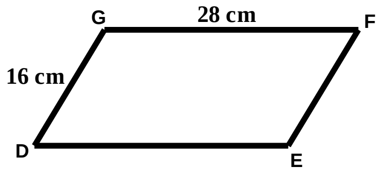
$$\text{Q Matrix}=\begin{bmatrix}1 & 0 & 0\\ 1 & 1 & 0\\ 1 & 0 & 1\end{bmatrix}$$

Table 1. Problem attributes

No.	Attribute		Attribute	Problem Number
1	Quadrilateral properties	Properties of a square	A1	1 and 2
2		Properties of a rectangle	A2	3 and 4
3		Properties of a square	A3	5 and 6
4		Properties of a parallelogram	A4	7 and 8
5		Properties of a rhombus	A5	9 and 10
6		Properties of a kite	A6	11 and 12
7		Properties of a trapezoid	A7	13 and 14
8	Perimeter of a Quadrilateral	Rectangle perimeter	A8	15 and 16
9		Rhombus perimeter	A9	17 and 18
10		Kite perimeter	A10	19 and 20
11		Rectangle perimeter	A11	21
12		Square perimeter	A12	22
13	Area of a Quadrilateral	Rectangle area	A13	23 and 24
14		Square area	A14	25 and 26
15		Parallelogram Area	A15	27 and 28
16		Rhombus area	A16	29 and 30
17		Kite area	A17	31 and 32
18		Trapezoid area	A18	33 and 34
19	Triangle properties	Properties of a isoscele triangle	A19	35
20		Properties of a scalene triangle	A20	36
21		The sum of angles in a triangle	A21	37 and 38
22		The relationship between the interior and exterior angles of a triangle	A22	39 and 40
23	Circumferemce of Triangle	Circumferemce of Triangle	A23	41 and 42
24	Area of a Triangle	Area of a Triangle	A24	43 and 44

The researchers and Indonesian Realistic Mathematics Research and Development Center Team (PRP-PMRI) at Syiah Kuala University developed the test items based on the attributes mentioned earlier. The questions were presented as multiple-choice items, with four answer options provided. The options included one key option and three distractor options, which could be justified by various reasons for student responses or by using polytomous scoring (Sutiarso, Rosidin, & Sulistiawan, 2022). The distractor options were organized according to their level of difficulty, as follows: Distractor 0 (D0) represented the most challenging option, Distractor 1 (D1) represented a moderately difficult option, and Distractor 2 (D2) represented the easiest option, while D3 served as the key option.

Table 2. Problems and options

	Attribute	Problem	Options
Perimeter of quadrilateral	A10: Determine the perimeter of the parallelogram	Look at the following figure!  The perimeter of the parallelogram DEFG is .... a. 44 cm b. 56 cm **c. 88 cm** d. 448 cm	Option A (D2) K = 28 + 16 K = 44 cm Option B (D0) K = 2 × 28 K = 56 cm **Option C (D3)** K = 2(16) + 2(28) K = 32 + 56 K = 88 cm Option D (D1) K = 28 × 16 K = 448 cm

The test comprised 44 items and underwent validation by a panel of experts consisting of three Mathematics education lecturers and four subject teachers. The validation results confirmed all 44 items in the test are feasible to use.

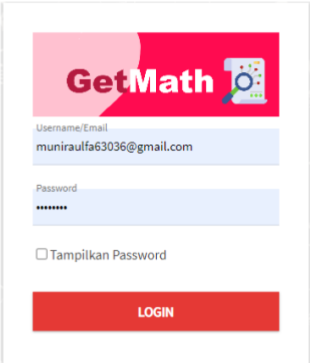
Item analysis based on Item Response Theory (IRT) was conducted using the R program, which enabled the calculation of difficulty index, validity, and reliability parameters. The analysis indicated that, generally, the validity level of the items ranged from 0 to 1, with only three negatively worded items. Additionally, the test exhibited high reliability, with an average score of 0.998. This reliability level was further divided into the following attributes: reliability of test items measuring properties of triangles and quadrilaterals (0.999), reliability of test items measuring the perimeter of triangles and quadrilaterals (0.997), and reliability of test items measuring the area of triangles and quadrilaterals (0.997). These findings were obtained from the R Studio application and verified manually. Table 3 provides the validity level for each test item.

Table 3. Level of validity of each item

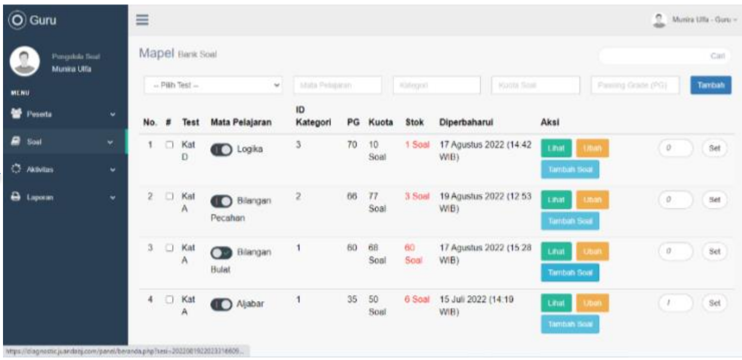
Problem	1	2	3	4	5	6	7	8	9	10	11
Validity	-0.104	0.355	0.180	0.378	0.414	0.346	0.339	0.267	0.238	0.419	0.054
Problem	12	13	14	15	16	17	18	19	20	21	22
Validity	0.194	0.258	0.501	0.392	0.087	0.459	0.322	0.206	0.338	0.280	0.346
Problem	23	24	25	26	27	28	29	30	31	32	33
Validity	0.612	0.229	0.171	0.113	0.469	0.248	0.325	-0.011	0.291	0.445	0.393
Problem	34	35	36	37	38	39	40	41	42	43	44
Validity	0.139	0.362	0.519	0.283	0.354	0.101	0.443	0.020	0.158	-0.049	0.272

The assessment comprised two sessions. The first session administered a diagnostic test to 24 students via the GetMath e-learning platform. The test comprised multiple-choice problems to identify the student's strengths and weaknesses in the subject matter. The second session was conducted on a different day. Six students were given a paper-and-pencil test that consisted of modified versions of the questions from the previous session. The test consisting of long answer problems assessed students' ability to construct coherent and comprehensive responses to the problems. After the test, unstructured interviews were conducted with the six students to confirm their understanding and reasoning behind their answers.

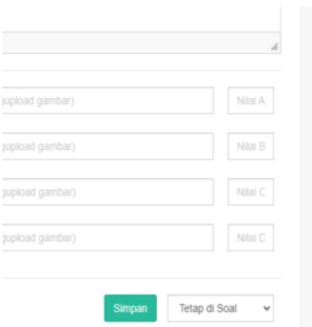
Valid and reliable test items were uploaded to the GetMath e-learning account. The test consisting of 44 items was administered through the GetMath e-learning website, which can be accessed via the http://prp-pmri.unsyiah.ac.id/getmath page. Figure 1 presents the displays of the GetMath account when logging in and inputting the problems.



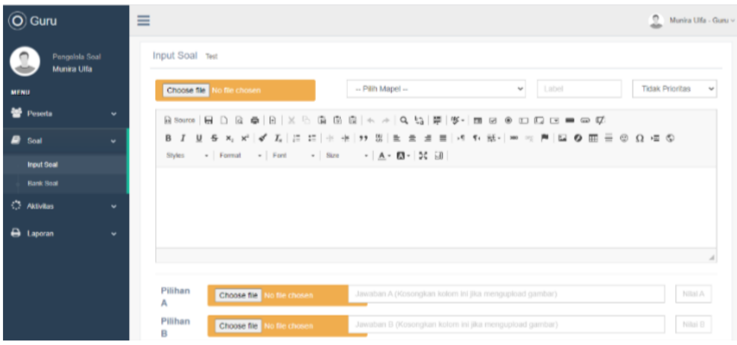
GetMath account display before login



GetMath account display after login



The screen of GetMath account to save the input problems



The screen of GetMath account for inputting the problems

Figure 1. Display of GetMath account

The focus of this research is to analyze errors based on Cooney's theory which classifies the types of students' mathematical errors into conceptual, principle, and verbal errors. Analysis of types of errors in terms of concepts, principles, and verbal plays an important role in knowing the forms of student barriers in achieving ideal learning outcomes (Yusmin, 2017).

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Table 4. Error indicators were used in this study (Cooney et al., 1975)

Error Aspect	Indicator	
	Error According to Cooney	Error in the study
Concept	• Inability to remember one or more of the conditions necessary for an object expressed in terms that represent it. • Inability to classify objects as conceptual examples of non-examples of objects.	• Students ignore the unit perimeter and area, and students do not include units. • Students use the unit of circumference as a unit of area. • Students do not understand and differentiate the types of plane geometry, signs, and symbols. • Students do not use formulas correctly.
Principal	• Inability to perform algebraic calculations or operations • Inability to state a principle	• Students have difficulty doing calculations or algebraic operations. • Students can abstract the patterns from pictures but cannot conclude what they are looking for.
Verbal	Inability to use concepts and principles	• Students incorrectly transform the problems. • Students use the concepts and principles incorrectly.

Table 5. Indicators of the interview guidelines

No.	Interview Indicators
1.	Students' understanding of reading and understanding the problems
2.	Students' understanding of the concepts in the problems.
3.	Students' ability to use the right formula.
4.	Student's numeracy ability
5.	Students' ability to draw conclusions.

Results and Discussion

The diagnostic test results showed that students' ability to solve test questions was relatively low and had not fulfilled the expected learning objectives. This was concluded based on the scores of students below the Minimum Criteria of Mastery Learning (KKM) at the research location (75). Table 6 presents the results of student answer scores in intervals of 1-100.

Table 6. Students' scores

Subject	The number of correct items	Score	Subject	The number of correct items	Score
S1	19	43.2	S13	16	36.7
S2	14	31.8	S14	4	9.1
S3	15	34.1	S15	11	25
S4	17	38.6	S16	14	31.8
S5	10	22.7	S17	8	18.2
S6	21	47.7	S18	12	27.3
S7	16	36.4	S19	14	31.8
S8	20	45.5	S20	14	31.8
S9	12	27.3	S21	6	13.6
S10	13	29.5	S22	12	27.3
S11	15	34.1	S23	8	18.2
S12	17	38.6	S24	16	36.4

The test results revealed that students could not solve the flat shape questions correctly, so an in-depth analysis was needed to see the types of errors made by students so that they could be followed up with improvement efforts. Furthermore, six Grade 8 students were selected based on the types of student errors and students' inability to solve concept, principle, and verbal problems. The focused problems were Problems 9, 16, 24, 25, and 39, so the percentage of student errors was obtained based on these indicators, as presented in Table 7.

Table 7. Percentage of student errors based on error indicators

Errors	No of items	Students with errors	Total	Percentage
Conceptual	16	S1, S2, S3, S4, S5, S7, S8, S9, S11, S12, S13, S14, S15, S16, S17, S18, S20, S21, S22, S23, S24.	55	76.39%
	39	S2, S5, S7, S8, S11, S12, S13, S14, S15, S17, S18, S19, S21, S22.		
	34	S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S14, S15, S17, S18, S19, S20, S21, S22, S23, S24.		
Principal	9	S4, S5, S7, S8, S10, S11, S14, S16, S18, S19, S20, S22.	33	68.75%
	24	S1, S2, S3, S4, S6, S8, S9, S10, S11, S12, S13, SP1, S15, S16, S17, S18, S20, S21, S22, S23, S24.		
Verbal	25	S1, S3, S4, S6, S7, S8, S11, S12, S13, S14, S15, S17, S18, S19, S20, S21, S22, S23.	18	75%

Table 7 shows the percentage of student errors in solving conceptual, principle, and verbal problems is relatively high. These percentages are obtained from the total number of students who made errors on concepts or principles or verbal problems divided by the total number of students from each error category and multiplied by 100%. Furthermore, students were selected from each conceptual, principle, and verbal error indicator to become research subjects. So, six students participated in the session 2 test. Table 8 presents the six subjects and the types of errors that dominate their answers.

Table 8. The selected six research subjects

No.	Subject	L/P	Error Type	Subject Code
1.	S8	P	Conceptual	SC1
2.	S11	L	Conceptual	SC2
3.	S14	P	Principal	SP1
4.	S20	L	Principal	SP2
5.	S6	L	Verbal	SV1
6.	S21	P	Verbal	SV2

Note:
SC: The student with conceptual error
SV: The student with verbal error
SP: The student with principal error

The long-answer problems were given before the interview, and the question wording was edited according to the structure of the long-answer problems. Including long answer problems offers several advantages for researchers, as it facilitates the acquisition of in-depth information regarding student comprehension, identifies specific error types, assesses students' critical thinking abilities, evaluates their written communication skills, and encourages reflection and analysis. After the test, all subjects were interviewed with unstructured questions based on predetermined interview indicators. The selected subjects were willing to be re-tested and interviewed. Figure describes the test results and error interviews made by students in solving concept, principle, and verbal questions.

If the perimeter of a square is 72 cm and the width is 8 cm, find the length of the rectangle.

Figure 1. Conceptual problem 1

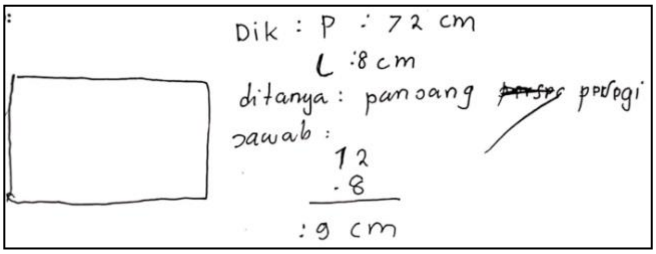


Figure 2. The answer to SC2

P	:	*Problem 1, why is this answer? (while pointing to the answer sheet) Please explain!*
SC2	:	*Because the problem a SCed for a rectangle*
P	:	*Oh, it is a rectangle, so what is aSCed? Is it the length, width, or else?*
SC2	:	*Width*
P	:	*What is the formula?*
SC2	:	*72 divided by 8, the result is 9 cm*

The results of the tests and interviews indicated that SC2 made a mistake in mentioning the information provided in the problem during the interview. However, the answer was almost correct. SC2 also made the mistake of applying the formula for the length of a rectangle when the perimeter is known. At first glance, it looks like SC2 has guessed the formula for the area of a rectangle to solve the problem, namely L = p × l, to determine the value of p = $\frac{L}{l}$. The SC2 error occurred due to poor mastery of the formula for the area and perimeter of a rectangle; students could not remember and differentiate between these formulas.

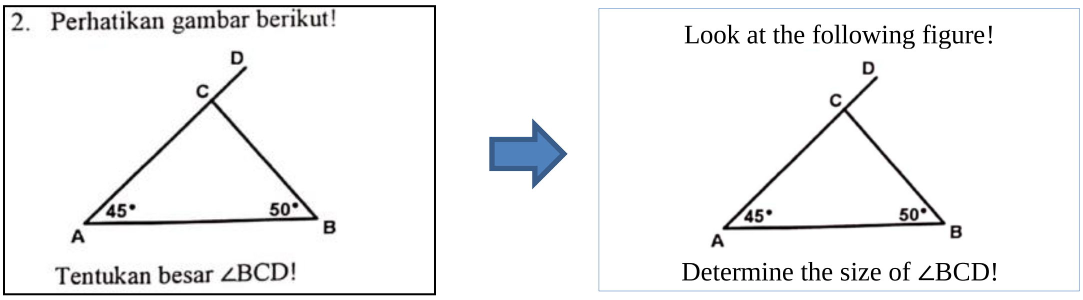


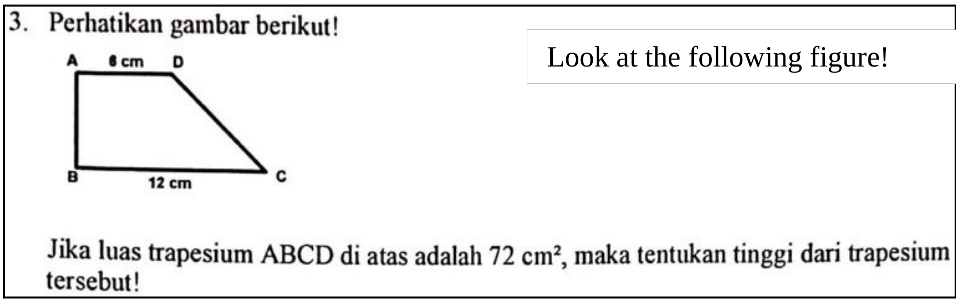
Figure 3. Conceptual problem 2

Figure 4. The answer to SC1

P : *For Problem 2, Please, explain what is known in this problem. What form is this (while pointing to Problem 2)*
SC1 : *Triangle*
P : *So, what is this number called? What is 45°?*
SC1 : *The length, isn't it?*
P : *Length, and then?*
SC1 : *This is the width (50°)*
P : *What is aSCed?*
SC1 : *The size?*
P : *What size?*
SC1 : *BCD*
P : *What does it read? (while pointing towards the symbol ∠)*
SC1 : *Less than*
P : *So, what is aSCed for something less than BCD?*
SC1 : *Yes*
P : *How do you get 60°?*
SC1 : *I don't know*
P : *Okay, I'm going to tell you, this is not a length but an angle, 45°, and this is an angle of 50°. What is aSCed is ∠BCD. So, 60 is the answer, isn't it?*
SC1 : *Yes*

The results of tests and interviews show that SC1 was unable to state the information given in the questions and made a mistake in stating the angle symbol (∠). SC1 also misunderstood the question and did not know the number of angles in the triangle, so SC1 was unable to solve the problem with the correct solving procedure.

Evidently, some students have encountered difficulties comprehending the sum of angles in a triangle, which is 180°. Moreover, the subjects demonstrated a lack of proficiency in distinguishing between angle symbols (∠) and the less than symbol (<). This observation indicates a weakness in their understanding of triangle properties, which may contribute to their struggles.


3. Perhatikan gambar berikut!

Jika luas trapesium ABCD di atas adalah 72 cm², maka tentukan tinggi dari trapesium tersebut!

Look at the following figure!

Figure 5. Conceptual problem 3

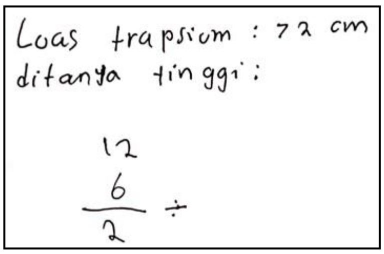
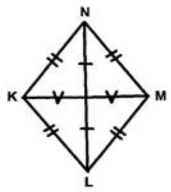


Figure 6. The answer to SC2

P	:	*What is AD?*
SC2	:	*This is width, uh, this is length (while pointing at the top side of the trapezoid. This is wide (while pointing at the bottom side of the trapezoid)*
P	:	*Do you remember the formula?*
SC2	:	*No*
P	:	*So, why the answer is 2?*
SC2	:	*12 divided by 6*

The results of tests and interviews showed that SC2 could conclude the information provided in the questions but did not know the formula for finding the area of a trapezoid and the height of a trapezoid if you know the area and length of the top side and the base side. Hence, SC2 guessed the answer by dividing the length of the top side by the base side.

1. **Perhatikan gambar belah ketupat berikut!**



Jika panjang KN = (9x – 15) cm dan ML = (5x + 9) cm, maka tentukan nilai x agar sifat belah ketupat terpenuhi!

Figure 7. Principal problem

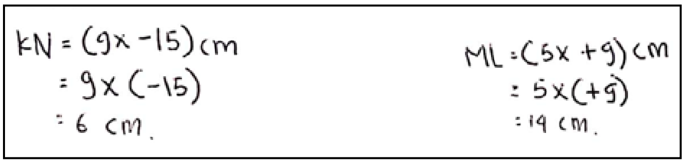


Figure 8. The answer to SP2

P	:	*Ok. Why did you answer 6 and 14? (Pointing to the answer sheet)*
SP2	:	*9 minus 15*
P	:	*What is it?*
SP2	:	*6*
P	:	*Then?*
SP2	:	*ML 5x + 9, so it is 14*

The results of tests and interviews showed that SP2 made an error in the calculation or algebraic operations. SP2 was also mistaken in doing the calculations and did not know the meaning of a variable x. SP2 immediately subtracted 9 from 15, which should be -6 but SP2 said it was 6.

Lantai sebuah gedung berbentuk persegi dengan luas 81 m^2 akan dipasangi keramik dengan ukuran 30 cm x 30 cm. Hitunglah banyaknya keramik yang dibutuhkan!

Figure 9. Verbal problem

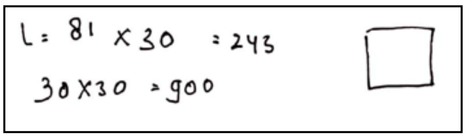


Figure 10. The answer of SV2

P	:	*What is known from the problems?*
SV2	:	*8 times 30*
P	:	*What is 8?*
SV2	:	*The area*
P	:	*Which area is known?*
SV2	:	*Square*
P	:	*Do you know which one is Square?*
SV2	:	*Yes*
P	:	*Can you draw it?*
SV2	:	*(Drawing)*
P	:	*You said the area is known, what is next?*
SV2	:	*The dimension of the rectangle*
P	:	*What is it?*
SV2	:	*30 cm*
P	:	*30 cm only?*
SV2	:	*Multiplied by 30 cm*
P	:	*What is aSCed?*
SV2	:	*Calculate the number of tiles needed!*
P	:	*So, you said a square, which one is square? The building or tiles. Which one is 30 centimeters wide? The 30 times 30, is it the building or the tiles?*
SV2	:	*The tiles*
P	:	*Ok, how do you solve the problem?*
SV2	:	*30 times 30 is 900*
P	:	*So, what about 81?*
SV2	:	*81 times 30 is 243*
P	:	*Why?*
SV2	:	*The area and the dimension*
P	:	*The area should be multiplied by the dimension.*
SV2	:	*Yes*

The results of the tests and interview revealed that SV2 was not able to transform the verbal questions correctly, so SV2 incorrectly presented the problem-solving procedure. SV2 was unable to distinguish the size of the building from the size of the tiles and was not wrong in transforming these measurements into a mathematical model. It seems that SV2 only guessed the answer because he was unable to apply the correct procedure to solve it.

Based on the results of the test and interviews for all problems (concepts, principles, and verbal), it was concluded that the types of errors made by students in solving plane geometry problems correspond to the indicators of errors, as presented in Table 9.

Table 9. The summary of error types

Error	Error type
Conceptual	Error in stating the angle symbol
	Error understanding the type of plane geometry given
	Misunderstood the problem
	Errors in concluding the information provided both in terms of the properties, circumference, and area of plane geometry.
	Not knowing the application of the right formula for plane geometry.
	Unable to solve the problem with the right solution procedure
Principal	Errors in performing algebraic calculations or operations and units.
Verbal	Error transforming problem
	Unable to use accurate concepts and principals

In education, it is common to encounter errors when solving mathematical problems. It is important to thoroughly understand and diagnose these types of errors in order to implement effective solutions and minimize their recurrence. Such errors can range from those made in basic mathematical materials to those in more complex materials that require high levels of reasoning, such as geometry problems.

Geometry is challenging for students, as it involves abstract concepts that cannot be easily taught through traditional methods such as lectures and knowledge transfer. The research by Fauzi and Arisetiawan (2020) supported this claim, as they found that geometry requires a process of concept formation through a series of student-led activities. Although students may be able to recognize shapes visually, they struggle with distinguishing between formulas for different types of planes, analyzing relationships between shapes, and solving problems related to plane geometry. Additionally, students often face difficulty comprehending instructions, mainly when modeling plane geometry problems related to real-world situations, as reported by Nirawati et al. (2022) Consequently, students frequently make errors when solving problems related to flat shapes. It is essential to identify and diagnose these errors thoroughly to help educators develop effective solutions and minimize the occurrence of these errors in the future.

The Covid-19 pandemic has resulted in a shift towards online learning, which necessitates educators to develop creative and innovative teaching methods and strategies that are suitable for online learning. However, various issues have emerged, such as constraints related to infrastructure and facilities, internet connectivity, teacher errors in managing students, and a lack of technical expertise. Diliberti and Kaufman (2020) argued that the nature of online learning imposes limitations on the interaction between teachers and students, resulting in a reduced ability for teachers to effectively engage with and support all students. According to Jamila et al. (2021) students face several challenges while learning at home, including a lack of resources to support online learning, such as smartphones or laptops. Inadequate internet access is another challenge, and students may have limited access to the internet due to the high cost of data plans. As a result, some students are unable to participate in online learning.

Online learning has brought about some challenges for teachers and students alike. Teachers must develop innovative and creative ways to design appropriate learning methods and strategies that can be applied during online learning. However, problems have arisen, such as limited access to facilities and infrastructure, poor internet connection, teacher errors in controlling students, and inadequate teacher knowledge in using technology. Students face numerous challenges, such as a lack of access to media such as smartphones or laptops, inadequate internet network facilities to support online learning, and limited access to the internet network due to the high cost of data.

Furthermore, some teachers share learning materials such as PowerPoint presentations and videos through WhatsApp groups, but only a few students view or download them. Some students log in to attend classes only to fill in attendance and carry out other activities, with some even turning off their cameras during Zoom or Google Meet sessions. Attendance and assignments are the most important things for students when entering class. Unfortunately, some students cheat by copying answers from their peers or even getting assignments done by their families, tutors, or neighbors. These issues have made online learning less effective and optimal for teachers and students (Jamila et al., 2021).

Mastering mathematical material, particularly geometry, often requires an extended period to understand all the concepts. However, due to time constraints, teachers often SCip teaching the overall geometric material according to the indicators. This challenge is further amplified in online learning systems, where the duration is shortened. Rajib and Sari (2022) research found that the online learning process has been reduced to 1-2 hours from 2-3 hours or 30 minutes per lesson from 45-50 minutes. Dewi, Maimunah, and Roza (2022) also identified several challenges encountered during the online learning of geometry material, from delivering material to evaluating difficult geometry questions. Consequently, students experience learning loss during online learning and make mistakes in solving plane geometry problems, including conceptual, principle, and verbal errors.

Conclusion

This study concluded that the percentage of errors students make in solving plane geometry problems using E-learning diagnostic tests is relatively high. The errors made by students vary widely, including errors related to concepts, principles, and verbal aspects. Specifically, 76.39% of students made mistakes in solving concept questions, 68.75% in principle questions, and 75% in verbal questions.

Conceptual errors made by students include errors in understanding the angle symbol, inability to identify the type of shape given, difficulty in concluding the provided information regarding the properties, circumference, and area of the shape, lack of understanding in applying the shape formula, and inability to solve problems using the correct procedure. Conversely, principal errors refer to errors made in performing algebraic calculations or operations and using units. Finally, verbal errors include difficulties transforming questions and inappropriately using concepts and principles.

The findings of this study are anticipated to assist teachers in promptly identifying errors made by students when solving plane geometry problems. These findings can serve as a valuable reference for mitigating student errors by strengthening their conceptual understanding of plane geometry. Furthermore, they can serve as a supplementary resource for other researchers seeking to develop learning models that effectively address learning loss in plane geometry.

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