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Learning Trajectory of Quadrilateral Applying Realistic Mathematics Education: Origami-Based Tasks

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Abstract: There are various misconceptions students have when studied quadrilateral which encourages efforts needed to overcome these misconceptions. This study aims at overcoming misconceptions by designing learning trajectories in the topic of Quadrilateral applying the Realistic Mathematics Education (RME). Design research carried out at one of junior schools in Garut was used in this research in which thirty-one grade VII students took the participation. The data were collected by providing activity sheets and student worksheets, interviews, and classroom observations. The findings suggest that the learning trajectory of quadrilateral consist of four activities, i.e., origami shape, finding the properties, sulid (stacking sticks), and origami puzzle. From these activities, students can understand the concept of a quadrilateral smoothly. In general, the learning trajectory of a series of learning games/activities can help students to understand, develop, and solve problems in various materials.

INTRODUCTION

Geometry is a branch of mathematics (Aydoğdu & Keşan, 2014; Sukirwan, et al. 2018), which has main portion in the education curriculum in Indonesia because geometry is taught from elementary to high level education. One of the geometry topics in school mathematics is quadrilateral. In the elementary school level, quadrilateral topic is taught from 1st grade to 4th grade. The Ministry of Education and Culture (in Darmawati, Irawan, & Chandra, 2017) stated that in the junior high school level, quadrilateral is taught again with standard competencies of analyzing the characteristics of various quadrilaterals based on sides, angles, relationships between sides and between angles and deriving formulas for determine the perimeter and area of a quadrilateral. Quadrilateral knowledge is the requirement knowledge for studying quadrilateral and similarity (Ardianzah & Wijayanti, 2020).

Although the topic has been thought since elementary school, there are many students in junior high school who make misconceptions regarding it (Hartono, 2020; Rahayu & Afriansyah, 2021). Nadjib (2016) suggested that misconceptions of students were due to a lack of understanding of

the parts and characteristics of quadrilateral making them difficult to understand the characteristics of each quadrilateral. Moreover, the misconceptions were due to lack of understanding regarding the concepts and principles of each quadrilateral so that it is difficult to understand the relationship between each quadrilateral and the difficulty of defining each quadrilateral. Furthermore, an observation made by Sopiany and Rahayu (2019) to the MTs Asy-Syifa students suggested that there were still many misconceptions. One of the misconceptions created by students was applying the formula mistakenly and ignoring to write down the units in the answer, for instance length in centimeters (cm).

Based on some descriptions of those misconceptions, a learning innovation is needed in a design of a learning trajectory activities that can support students to understand the concept of quadrilateral. The learning trajectory is a learning design that considers students' thinking levels directly (Andrews-Larson, Wawro, & Zandieh, 2017; Rich, et al., 2018; Widodo, et al. 2019) of which students learn in their way and actively create their knowledge continuously. The learning trajectory describes students' thinking through various activities to achieve learning goals. Through this activity, students are demanded to understand the concept and see the meaning carried in the material being studied and its connection to everyday life (Buelow, et al. 2018; Tanujaya, et al. 2021).

One of the learning innovations in promoting a learning trajectory is the application of *Pendidikan Matematika Realistik Indonesia* (PMRI) approach. PMRI has a characteristic in the learning process, namely the use of context (Mariani, 2018). It could be Indonesian or cultural context (Fauziah & Putri, 2020). Learning with PMRI gives possibilities for students to rediscover and build mathematical concepts based on realistic problems presented by the teacher (Majid, 2017; Afriansyah, 2021). Realistic situations in learning enable students to use their informal knowledge to solve problems (Sumirattana, Makanong, & Thipkong, 2017). The PMRI approach is one approach that applies a real-world context in the transfer of learning (Edo & Samo, 2017), in which it is expected that students will be highly motivated because they assume that mathematics is strongly connected to the real world. PMRI is an adaptation of the Realistic Mathematics Education (RME) approach which was initiated by Hans Freudhental from the Netherlands (Zulkardi, Putri, & Wijaya, 2020). Gravemeijer (Arwadi, et al., 2017; Zubainur, et al., 2020), RME has five characteristics which are the operationalization of RME principles, namely: 1) the use of contexts; 2) the use of models, bridging by horizontal-vertical instrument; 3) students' contribution; 4) interactivity; and 5) intertwinement.

By building learning trajectories with this approach, it is expected that students can avoid misconceptions that usually happen when studying quadrilateral. On this paper, the researcher proposed to design the learning trajectory of quadrilateral by applying the RME.

METHOD

This study employs design research (Van den Akker, et al., 2006). Design research can help determine what kind of learning activities need to be designed to help students understand quadrilaterals. Through these three stages of design research (Afriansyah, et al., 2021), we can see a detailed picture of learning in the classroom along with an analysis of the results of students' answers carried out in each activity. The purpose of this study is to describe the learning trajectory in the topic of quadrilateral using the RME. There are three phases in this design research, namely: preliminary design, teaching experiment, and retrospective analysis (Gravemeijer & Cobb, 2006).

The preliminary design formulates a learning that was applied in the experimental design phase. There were three activities in this phase. Firstly, the school in general as well as, the classroom including the teacher and the students in particular were observed. Secondly, a number of references related to the various difficulties of students in understanding the concept of a quadrilateral were identified. Thirdly, a number of references related to a series of learning activities related to the Realistic Mathematics Education (RME) approach were analyzed. These three activities are used as the basis of information in designing the Hypothetical Learning Trajectory (HLT), consisting of three components: the learning activities, the learning objectives, and the conjectures or the hypotheses in the learning process. This hypothesis serves as one of the frameworks of thinking in preparing the design of learning activities and becomes the reason for developing learning activities that have been designed. An overview of the series of learning activities and their assumptions is described in Table 1.

Activities	Main Goals	Conjectures
Origami Shape	Encouraging students to know the definition of quadrilaterals	Students must arrange each piece of shape into a variety of quadrilaterals that can be formed. Students draw each quadrilateral on the table provided and provide an explanation for each image that has been found. Students are only able to recognize quadrilaterals but do not understand the concept definition of a quadrilateral. Students are wrong in determining the quadrilaterals that are presented, determining whether they are quadrilaterals or not.
Finding The Properties	Supporting students to find out the properties of quadrilaterals	Students can write down the properties of quadrilaterals after going through problem-solving so that students are not only based on memorization. Students are confused to distinguish the properties of each type of quadrilateral. Students assume that the rectangle has only one position, specifically the horizontal position.

Sulid Activity	Supporting students to find the formula for the perimeter of a square and a rectangle	Students do the activity of sticking sticks that have been cut the same length on each edge of the square and rectangular images. Students are directed to find the concept of the perimeter of a square and a rectangle by themselves before solving the problems presented. Students do not understand the perimeter problems presented so that when solving these problems students are confused about what formula to use. Students do not write perimeter units in solving the problems presented.
Origami Puzzle	Assisting the students to find the formula for the area of a square and a rectangle	Students do the activity of pasting origami paper cut into small squares on each square and rectangular image. Students are still confused about solving the area problems presented. Students are wrong in writing the unit area in solving the problems presented.

Table 1: The Overview of Activity and Conjecture of The Learning Process

The teaching experiment was carried out in two cycles, namely the teaching experiment and the pilot experiment. In the previous step, the HLT which had been designed in an experimental experiment was applied in a small group learning process consisting of six students, was selected purposively. The aim was to see how far the learning series that had been designed could explore students' strategies and understanding. Then, the HLT was refined and improved based on the findings from the first cycle. In the second cycle, namely the teaching experiment, the HLT revision was implemented in a natural class setting. Data collection techniques were carried out through classroom observation using videos and student worksheets. In addition, other group discussions by recording to describe students' understanding during the learning process.

In the retrospective analysis stage, all data were obtained, collected, and analyzed. The hypotheses developed in the initial HLT were compared with the results of the implementation of the learning trajectory. Next, an investigation was conducted on the role of learning in analyzing how students gain an understanding of the quadrilateral concept. This HLT revision is applied in the next cycle and analyzed based on the implementation results. This analysis activity was carried out repeatedly depending on the number of cycles carried out, and in this study, only two cycles were carried out.

The research was carried out at one of junior schools in Garut in which thirty-one students participate as the research subject. They were alternately taught in a schedule setting. The whole

schedule of the research activities is presented in Table 2. Three students were selected as the following participant subject to arrange the interview. The three students were chosen based on the difference of their abilities, i.e.: one student each with high, medium, and low abilities.

No	Date	Activities/Topics
1.	November 21, 2020	Quadrilateral definition
2.	November 25, 2020	Quadrilateral properties
3.	November 28, 2020	The perimeter of square and rectangle
4.	December 2, 2020	The area of square and rectangle
5.	February 6, 2021	Conducting interviews with the selected participants

Table 2: Schedule of Activities

The research was carried out with limited face-to-face learning because it was still in the Covid-19 pandemic condition. The data was collected by providing activity sheets and student worksheets and doing interviews and observations. The given student worksheets are in the form of tests consisting of questions about the description of quadrilateral. The interviews are designed to enable the researchers in obtaining information directly from students. Meanwhile the observations are applied to observe the learning process of Realistic Mathematics Education approach.

RESULTS

The learning trajectory design in this study is a description of student activities in learning the topic of quadrilaterals applying Realistic Mathematics Education approach. The learning trajectory design includes four activities carried out for four meetings covering the definition of quadrilaterals, the properties of quadrilaterals, the perimeter of a square and a rectangle, and the area of a square and rectangle.

Activity 1: "Origami Shapes" Game

The learning goals of activity 1 are that students can identify and understand quadrilaterals and are able to represent quadrilaterals. In this activity, firstly, teacher gave contextual problems by giving examples of rectangular images, such as images of windows, kites, and diamonds. Next, teacher assigned the activity Sheet 1 which contained the steps of the origami shape game which aims at identifying and understanding rectangular shapes and represent quadrilaterals. This activity was performed by six groups consisting of 5-6 students. Each group arranged the required tools and materials, such as origami paper, scissors, rulers, and stationery. Next, they returned to the origami papers of several quadrilaterals that are drawn with calculated sizes. Then each group arranged the pieces of the quadrilaterals into various other quadrilaterals (see Figure 1).

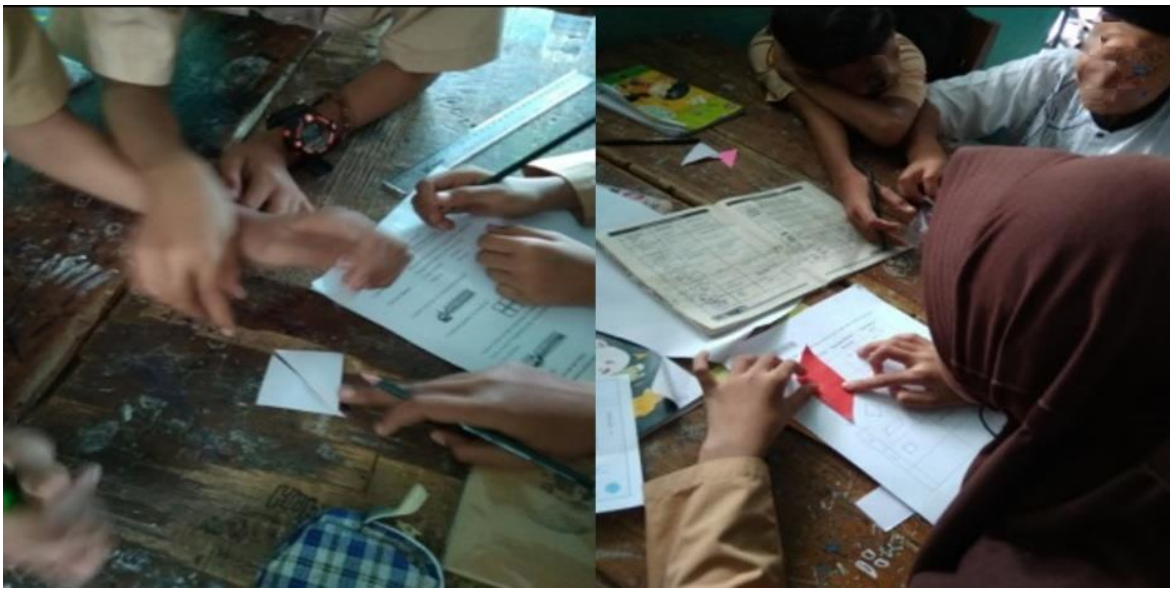
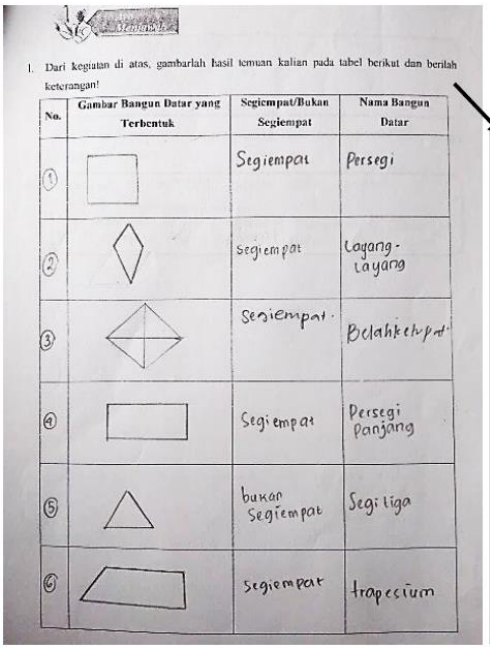


Figure 1: Activity 1 "Origami Shapes" Game

In this activity, the findings of each group are illustrated in the given table in which the students give an information for each image (see Figure 2). Students drew all quadrilaterals on the table, identified whether each image is quadrilateral, and wrote the name of each quadrilateral.



1. Dari kegiatan di atas, gambarlah hasil temuan kalian pada tabel berikut dan berilah keterangan!

No.	Gambar Bangun Datar yang Terbentuk	Segiempat/Bukan Segiempat	Nama Bangun Datar
①		Segiempat	Persegi
②		Segiempat	Layang-layang
③		Segiempat	Belahketupat
④		Segiempat	Persegi panjang
⑤		bukan Segiempat	Segitiga
⑥		Segiempat	trapesium

Let's Answer

1. From the activity above, draw your findings in the following table and give a description!

No.	Figure Two-Dimensional Shape	Quadrilateral/Not a Quadrilateral	Two-Dimensional Shape Name
1		Quadrilateral	Square
2		Quadrilateral	Kite
3		Quadrilateral	Rhombus
4		Quadrilateral	Rectangle
5		Not a Quadrilateral	Triangle
6		Quadrilateral	Trapezoid

Figure 2: Example of Student Work Results on Activity Sheet 1

After the activity was finished by all groups, the teacher then distributed Student Worksheets (see Figure 3) as a reinforcement of the initial understanding of rectangular shapes that must be done in groups. The answer from all groups at the problem number 1 i.e., mentioning all the shapes of figures in the picture, were not complete because the triangular shape is not mentioned. However, in the problems numbers 2 and 3 about quadrilaterals, all groups gave correct and complete answers.

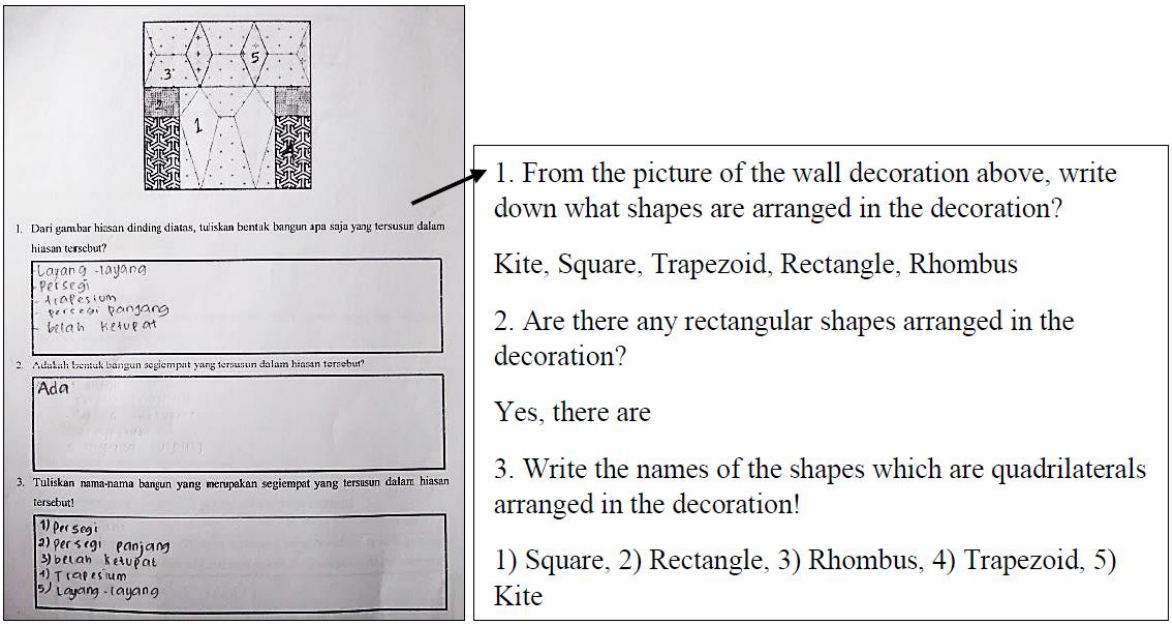


Figure 3: Example of Student Worksheet Answers 1

After that, the teacher shared problems related to quadrilaterals (Figure 4). This time the students worked independently.

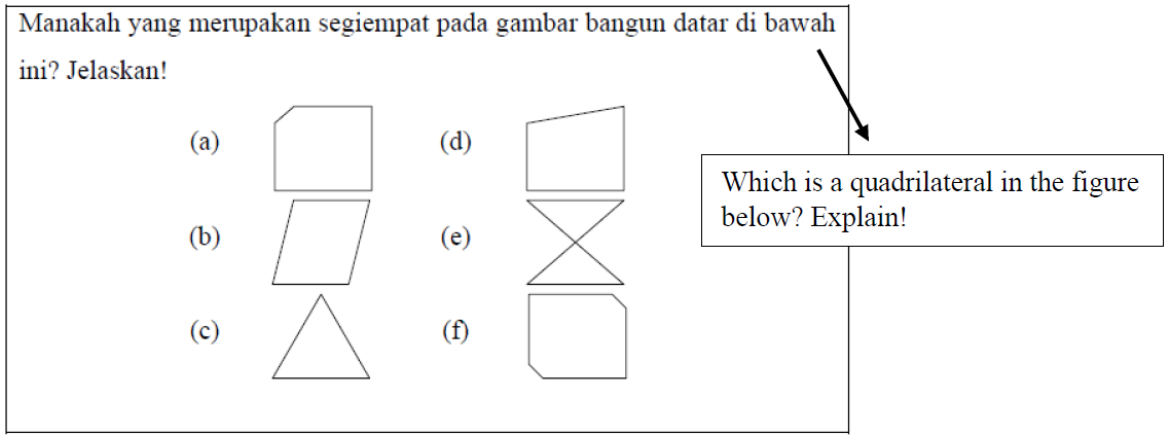


Figure 4: Activity Problem 1

After this problem is presented, the teacher begins to open a discussion with the students:

Teacher: *"Well, which one do you think is a quadrilateral?"*
S-17: *"Which (b) and (d)"*
Teacher: *"Anything else?"*
S-8 and S-26: *"No"*
Teacher: *"Why are (b) and (d) quadrilateral?"*
S-17: *"Because it has four sides"*
S-8: *"Because it has four angles, four sides"*
S-26: *"Because it has four sides and has four right angles"*

From the above conversation, the S-17 and S-8 have a good understanding of quadrilaterals, especially the S-8. While S-26 appears to have been misunderstood and upon closer inspection, in the image of S-26, the rectangle is square. In the discussion, the understanding of S-26 was successfully clarified by his friends.

At the end of the activity, it is likely that students already know and understand the definition and kinds of quadrilaterals as illustrated in the following interview fragment:

Teacher*: "What is the definition of a quadrilateral?"*
Students*: "A quadrilateral is a shape that has four sides and four angles".*
Teacher*: "Mention the kinds of quadrilaterals!".*
Students*: "The kinds of quadrilaterals include square, rectangle, rhombus, parallelogram, kite, and trapezoid".*

In the last activity, the teacher and the students together create conclusions about the activities that have been carried out in accordance with the learning goals to be accomplished at this first meeting.

Activity 2: "Find the Properties" Game

The learning goals of this activity are that students can understand and explain the properties of quadrilaterals and are able to solve problems in daily life linked to the properties of quadrilaterals. In this activity, firstly, the teacher presented several problems associated with the properties of rectangular shapes by presenting some examples of quadrilaterals on paper with squares. Next, the teacher assigned Activity Sheet 2 containing the steps of the game to obtain the properties of a quadrilateral which aims to understand and explain the properties of a quadrilateral. The game was performed by six groups of 5-6 students. Each group arranged the required tools and materials, such as origami paper, scissors, rulers, and stationery. Next, the students drew on origami paper a square measuring and a rectangle measuring. Then each of corner of the paper were named ABCD (see Figure 5).

Figure 5: Activity 2 “Find the Properties” Game

In this activity, the findings of each group are illustrated in the table given in which the students presented information for each image (see Figure 6, see Appendix 1, 2, & 3 for English version of students’ answer). In the answers of this students’ group, it appears that in the first question, students can mention the properties of squares and rectangles, namely there are parallel lines, diagonal lines, symmetry’s axes, and angles. In the second question, students can also write down the properties of other quadrilaterals, such as: rhombus, parallelogram, trapezoid, and kite.

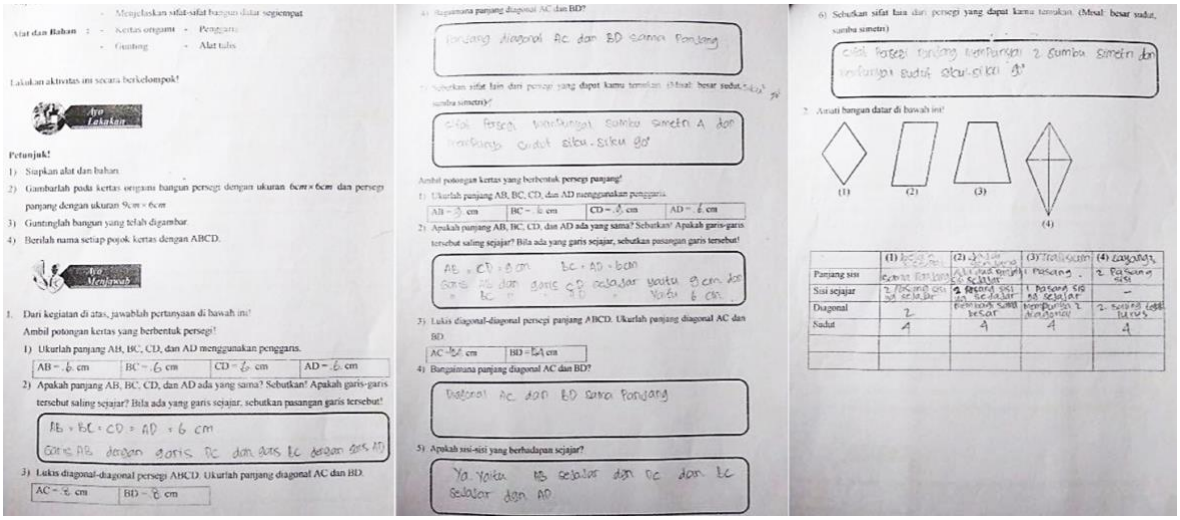
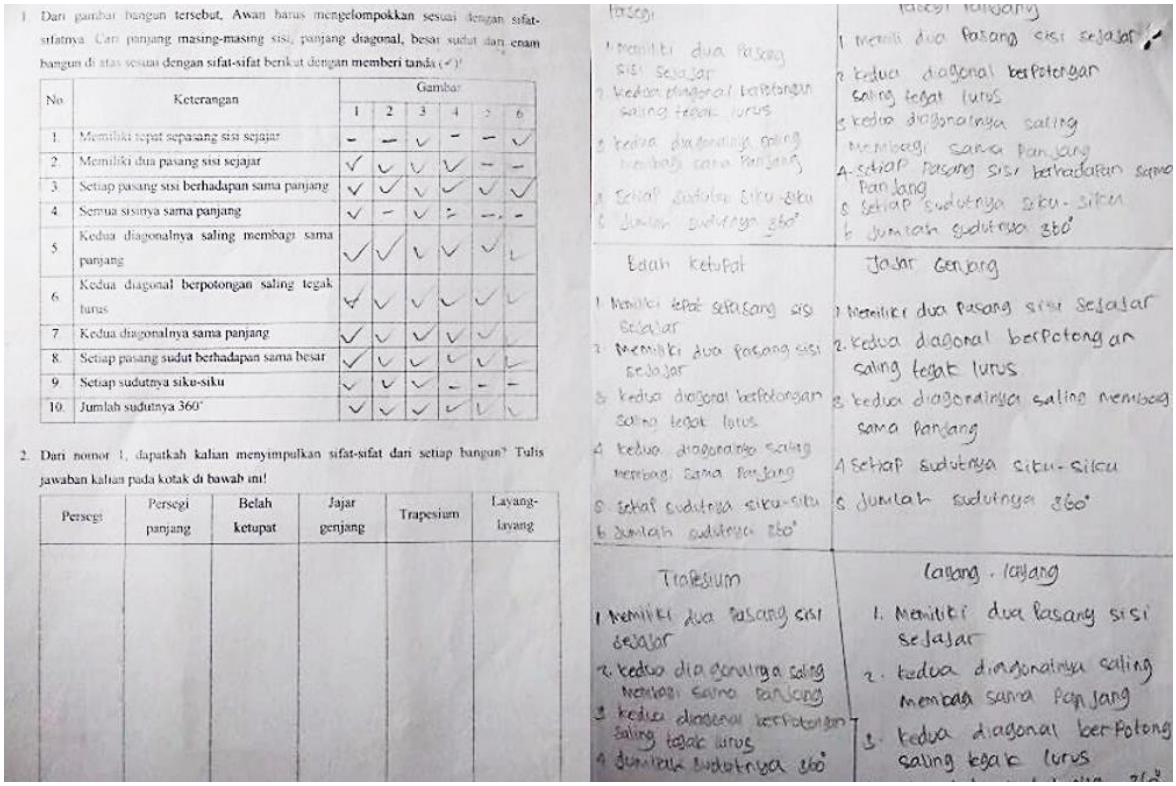


Figure 6: Example of Student Work Results on Activity Sheet 2

After the game was completed by all groups, the researcher then distributed Student Worksheets as a strengthening of understanding about the properties of quadrilaterals that must be done in groups (see Figure 7, see Appendix 4 & 5 for English version of students’ answer). Based on the student worksheet, it can be suggested that the answers given by students are correct and complete.

Students are able to describe the properties of various quadrilaterals, namely: square, rectangle, trapezoid, rhombus, parallelogram, and kite.



1. Dari gambar bangun tersebut, Awan harus mengelompokkan sesuai dengan sifat-sifatnya. Cari panjang masing-masing sisi, panjang diagonal, besar sudut dari enam bangun di atas sesuai dengan sifat-sifat berikut dengan memberi tanda (✓)!

No	Keterangan	Gambar					
		1	2	3	4	5	6
1.	Memiliki tepat sepasang sisi sejajar	–	–	✓	–	–	✓
2.	Memiliki dua pasang sisi sejajar	✓	✓	✓	✓	–	–
3.	Setiap pasang sisi berhadapan sama panjang	✓	✓	✓	✓	✓	✓
4.	Semua sisinya sama panjang	✓	–	✓	–	–	–
5.	Kedua diagonalnya saling membagi sama panjang	✓	✓	✓	✓	✓	✓
6.	Kedua diagonal berpotongan saling tegak lurus	✓	✓	✓	✓	✓	✓
7.	Kedua diagonalnya sama panjang	✓	✓	✓	✓	✓	–
8.	Setiap pasang sudut berhadapan sama besar	✓	✓	✓	✓	✓	✓
9.	Setiap sudutnya siku-siku	✓	✓	✓	–	–	–
10.	Jumlah sudutnya 360°	✓	✓	✓	✓	✓	✓

2. Dari nomor 1, dapatkah kalian menyimpulkan sifat-sifat dari setiap bangun? Tulis jawaban kalian pada kotak di bawah ini!

Persegi	Persegi panjang	Belah ketupat	Jajar genjang	Trapesium	Layang-layang

Figure 7: Example of Student Worksheet Answers 2

After the activity is complete, the teacher shares problems related to the properties of the quadrilateral (Figure 8) and students are required to work independently.

Diketahui sifat-sifat bangun segiempat berikut:

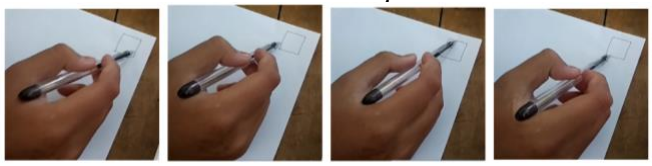
1) Memiliki dua pasang sisi sejajar
2) Semua sisinya sama panjang
3) Memiliki dua diagonal yang saling tegak lurus
4) Setiap sudutnya siku-siku

Tentukan bangun segiempat yang memiliki sifat-sifat di atas!

Know the properties of the following quadrilaterals:
1) Has two pairs of parallel sides
2) All sides are the same length
3) Have two diagonals that are perpendicular to each other
4) Every angle is a right angle
Determine the quadrilateral that has the above properties!

Figure 8: Activity Problem 2

After this problem is presented, the teacher and students begin to discuss:

Teacher: *"Well, now what kind of rectangles are built according to these characteristics?"*
S-17: *"Rectangle"*
S-8 and S-26: *"Square"*
S-17: *"Uh, Square"*
Teacher: *"Now try to draw a square shape!"*
(All students draw the square correctly)
Teacher: *"Show me which sides are parallel!"*
S-17: 
(S-17 shows two pairs of parallel sides)
Teacher: *"Are all the sides the same length?"*
S-8: *"Equal length"*
Teacher: *"Then, does it have two diagonals that are perpendicular to each other? Try Showing!"*
S-17: *"Yes, there are two diagonals"*
(S-17 shows two perpendicular diagonals)
Teacher: *"Finally, are every corner, right?"*
S-8 & S-26: *"Yes, right corner"*
Teacher: *"How big is the angle?"*
All students: *"90 degrees"*

From the conversation above, all students have a good understanding of the properties of quadrilaterals, especially the properties of squares.

At the end of the activity, it is likely that students have understood the properties of each type of quadrilateral as described in the following interview fragment:

Teacher: *"What are the properties of a square?"*
Students: *"The properties of a square include all the sides are the same length, have two pairs of parallel sides, have two diagonals that are perpendicular to each other and all angles are right angles"*.

In the last activity, researchers and students together make conclusions about the activities that have been carried out in accordance with the learning goals to be achieved at this second meeting.

Activity 3: "Sulid (Arrange Sticks)" Game

The learning goals in this activity are that students can understand and determine the perimeter of a square and a rectangle and are able to implement the concepts of the perimeter of a square and a rectangle to solve problems in everyday life. In this activity, firstly, the teacher gave some problems linked to the concept of the perimeter of a square and rectangle. Next, the researcher assigned Activity Sheet 3 containing the steps of the Sulid game (stacking sticks) which aimed at understanding and determining the perimeter of squares and rectangles. The game was performed by six groups of 5-6 students. Each group arranged the required tools and materials, such as sticks, paper glue, rulers, and stationery. Next, they arranged the unit sticks that have specific size. In this game, the number of sticks arranged in each shape is called the perimeter (see Figure 9).

Figure 9: Activity 3 "Sulid (Arrange Sticks)" Game

From these activities, the findings of each group are illustrated in the table given by presenting information for each image found (see Figure 10, see Appendix 6 & 7 for English version of students' answer). Based on the example of this activity sheet, students arrange sticks that have

been cut with the same size, which is 2 cm, on the edges of the square and rectangular shapes. Through this activity of arranging sticks, students can understand the meaning of the perimeter in squares and rectangles.

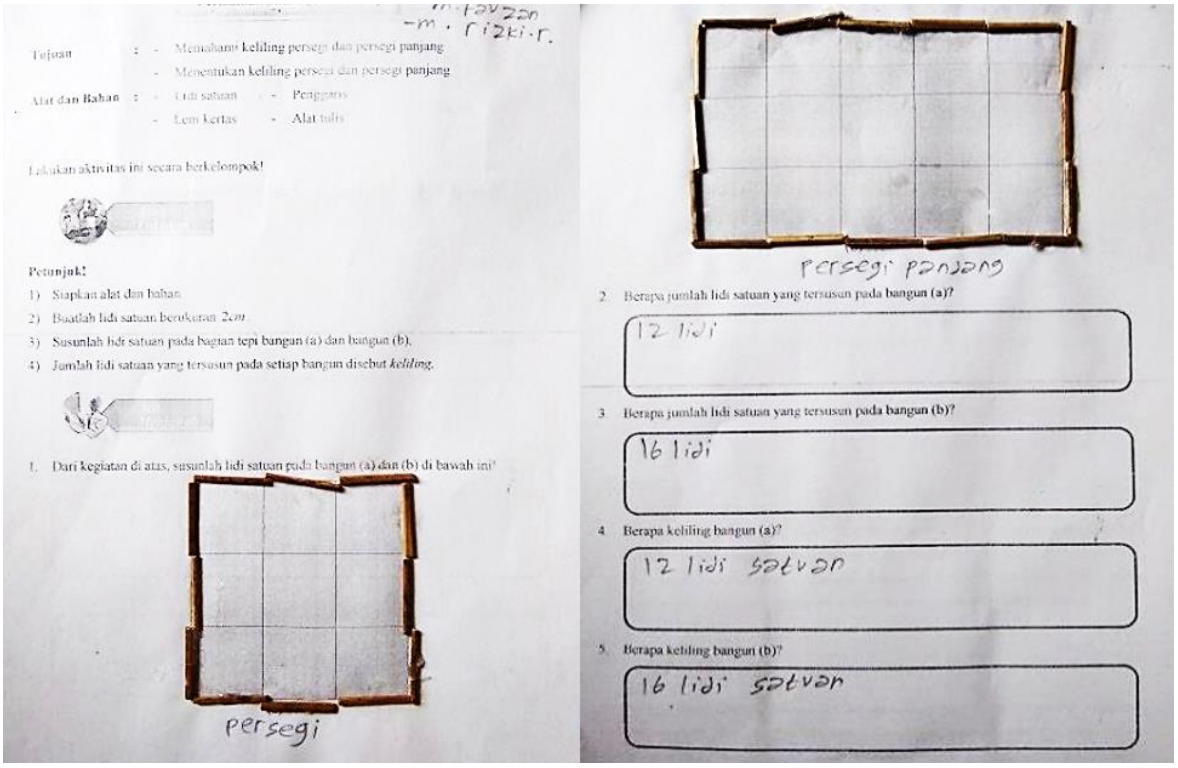


Figure 10: Example of Student Work Results on Activity Sheet 3

After the game was completed by all groups, the researcher then distributed Student Worksheets as a strengthening of understanding about the concepts of the perimeter of a square and a rectangle that must be done in groups (see Figure 11, see Appendix 8, 9, & 10 for English version of students' answer). Through the student worksheet, it can be seen that students can find the formula for the perimeter of a square and rectangle so that students are able to apply the formula to the given problem.

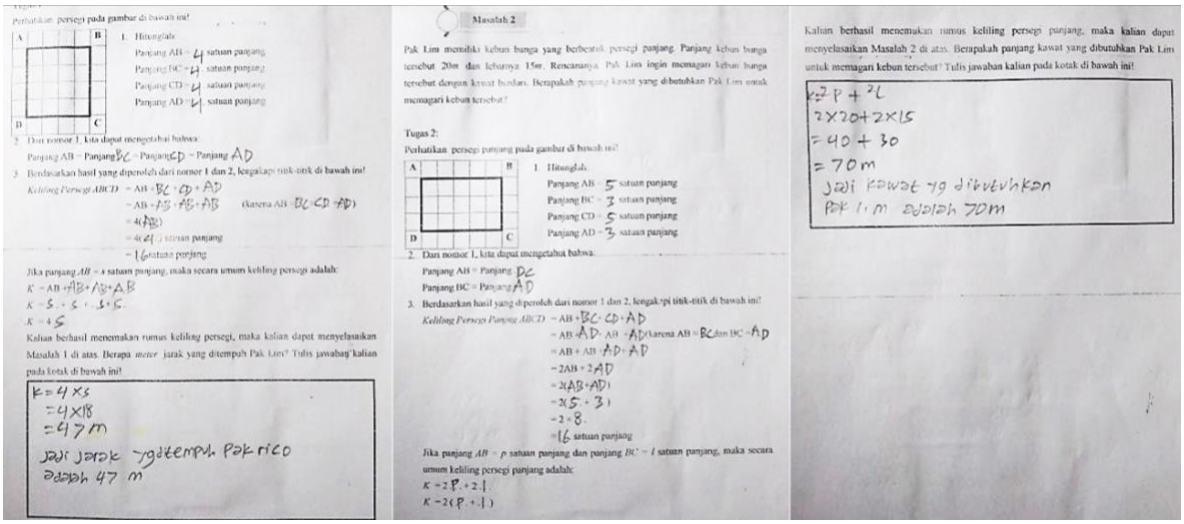


Figure 11: Example of Student Worksheet Answers 3

After the activity is finished, the teacher shares problems related to the perimeter of the rectangle (Figure 12), and students are required to work independently.

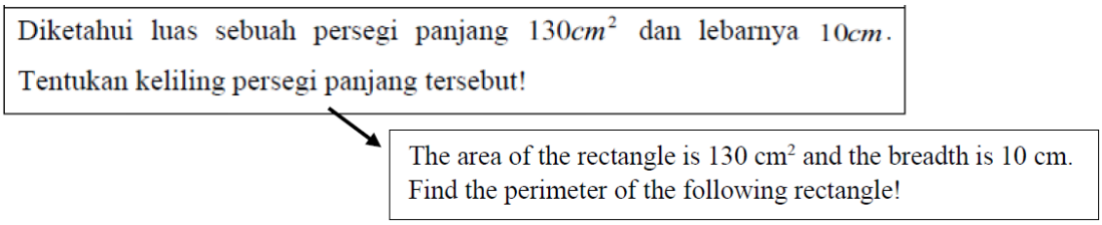


Figure 12: Activity Problem 3

After this problem is presented, the teacher and students begin to discuss:

Teacher: *"Well, what do you know and ask about from this question?"*
S-17: *"The area of a rectangle* $130cm^2$ *and its width* $10cm$*. Asked about the perimeter of the rectangle"*
Teacher: *"What is the formula for the perimeter of a rectangle?"*
S-26: "$L \times p \times k$"
Teacher: *"What are* $L \times p \times k$*?"*
S-26: *"Length, width, perimeter"*
Teacher: *"You are asked perimeter. Eh but, is that the correct formula?"*
S-26: *"Oh, so* $L \times p$*"*
Teacher: *"Are you sure?"*
S-26: (Silent)
S-17: *"No, it should be* $2 \times (p+l)$*"*
Teacher: *"Well, okay. Now try to explain how to do it!"*

S-17: *"From Luas = p × l. The area 130cm^2, Panjang = luas: lebar = 130:10=13. So, the length is 13cm".*
Teacher: *"After knowing the length, what is the next step?"*
S-8: *"To the perimeter formula"*
K = 2 × (p + l)
K = 2 × (13+10)
K = 2 × 23
K = 46cm^2
Teacher: *"Why the unit cm^2?"*
S-8: *"Because the width 10cm and the length 13cm, so that cm + cm = cm^2"*
Teacher: *"Oh, I see. Does anyone have another answer?"*
S-17:
K = 2 × p + 2 × l
K = 2 × 13 + 2 × 10
K = 26 + 20
K = 46
Teacher: *"Okay, it's different in the unit. So, the correct unit is?"*
(Most of the students say cm)
Teacher: *"Good, cm yes. Let's continue, from that question, why don't you just use the formula for the perimeter of a rectangle?"*
S-17: *"Because the length is unknown"*

From the conversation above, S-8 has a pretty good understanding of the perimeter of a rectangle, it's just that it's wrong to mention the unit. The S-17 has perfect understanding and is not selfish. S-17 pays attention to his friend's answer and always responds to his friend's answer. Meanwhile, S-26 seems not to understand, it can be seen from his presentation about the perimeter formula. Unfortunately, the teacher could not find out more about the answer.

At the end of the activity, it is likely that students already know and understand the concepts of the perimeter of a square and a rectangle as illustrated in the following interview fragment:

Teacher: *"Bu Sin plans to fence the flower garden with wire. The length of the flower garden is 7 m and the width is 5 m. What length of wire does Mrs. Sin need? What concept is used to solve the problem?"*
Students: *"To solve this problem, use the concept of the perimeter of a rectangle, so that the length of wire needed to fence Mrs. Sin's flower garden can be known".*

In the last activity, researchers and students together drew conclusions about the activities that have been carried out in accordance with the learning goals to be achieved at this third meeting.

Activity 4: "Origami Puzzle" Game

The learning goals in this activity are that students can understand and determine the area of squares and rectangles and are able to apply the concepts of square and rectangular areas to solve problems in daily life. In this activity, the teacher gave problems related to the concept of the square and rectangular area. Next, the researcher distributed Activity Sheet 4 which contains the steps of the origami puzzle game which aims to understand and determine the area of squares and rectangles. The game is performed by six groups of 5-6 students. Each group provided the required tools and materials, such as origami paper, scissors, paper glue, ruler, and stationery. Next, they drew on 6 square origami paper squares and arrange the unit squares in square and rectangular shapes. In this game, the number of unit squares that make up each shape is called the area (see Figure 13).

Figure 13: Activity 4 "Origami Puzzle" Game

From these activities, the findings of each group are illustrated in the table given by presenting information for each image found (see Figure 14, see Appendix 11 & 12). Based on the example of the activity sheet, students stick some origami papers that have been cut in a square shape 2 cm x 2 cm in length, on the square and rectangular pictures. Through this activity of sticking origami paper, students can understand the meaning of square and rectangular area.

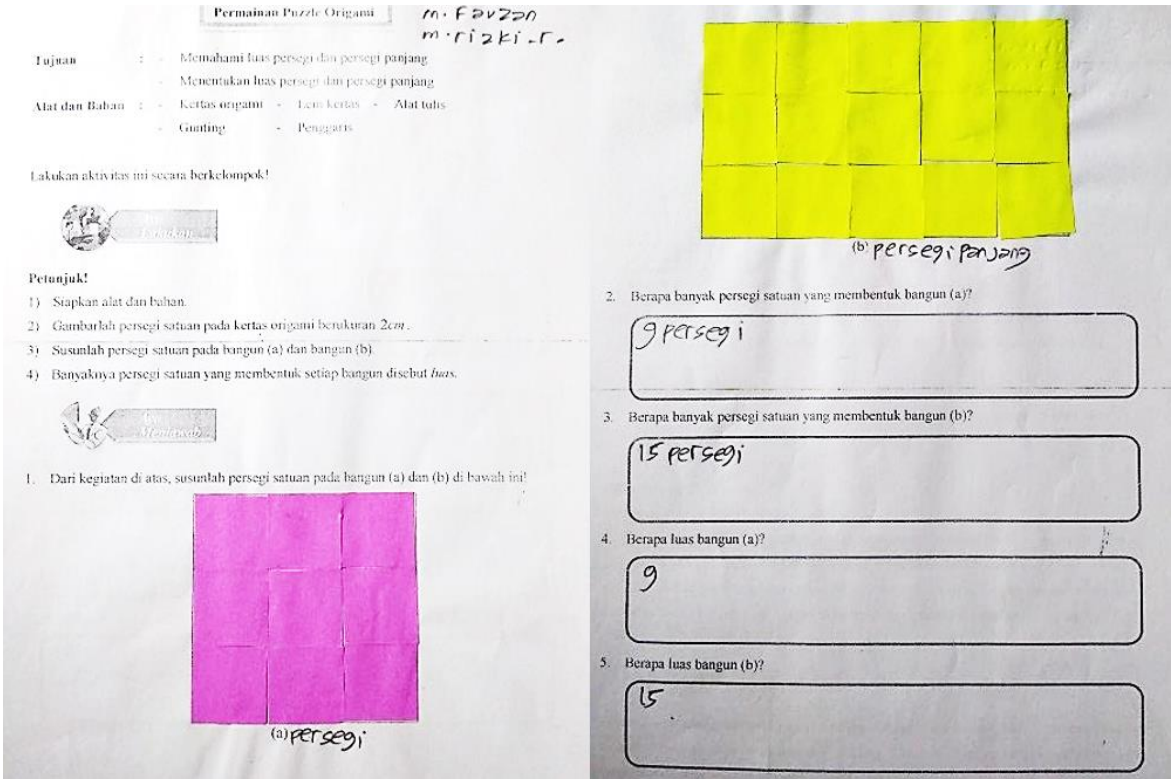


Figure 14: Example of Student Work Results on Activity Sheet 4

After the game was completed by all groups, the teacher then distributed Student Worksheets as a strengthening of understanding about the concept of the square and rectangular area that must be done in groups (see Figure 15, see Appendix 13 & 14 for English version of students' answer). In the worksheet, it can be seen that students can find the formula for the area of a square and rectangle so that students are able to apply the formula to the given problem.

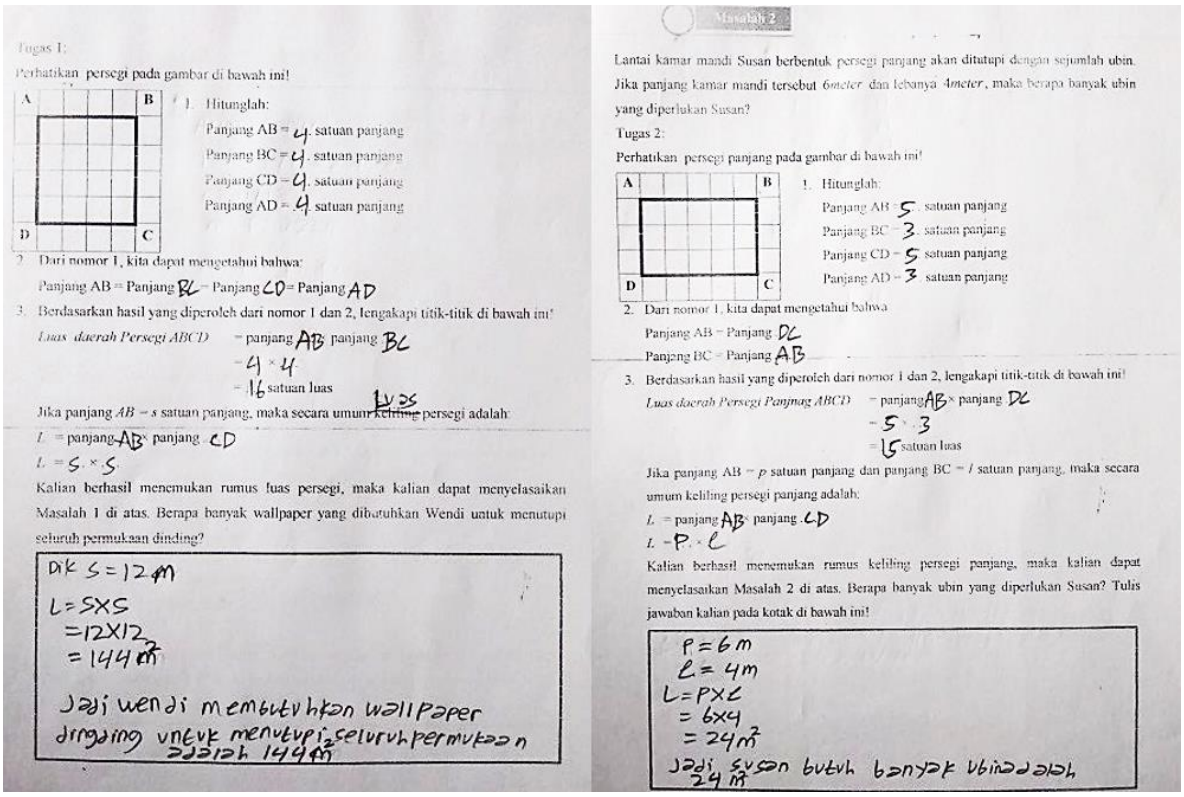


Figure 15: Example of Student Worksheet Answers 4

When finished, the teacher distributes problems related to the area of the rectangle (Figure 16) and students are required to work independently.

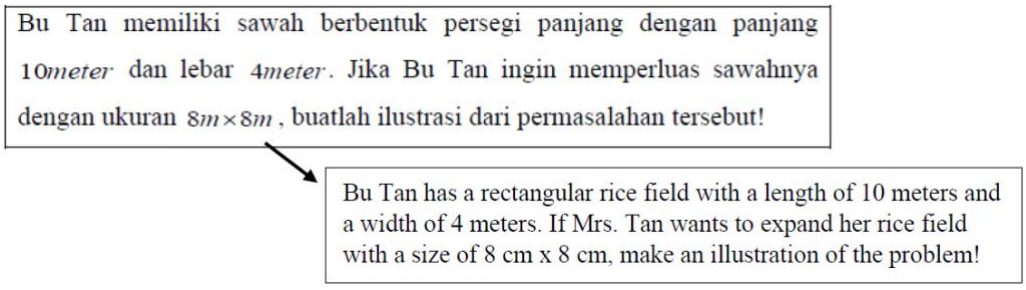
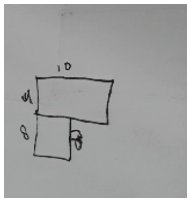


Figure 16: Activity Problem 4

Through this problem, the teacher invites students to discuss:

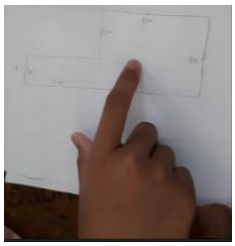
Teacher: *"Well, what do you know and ask about from this question?"*
S-26: *"Bu Tan has a rectangular rice field with a length 10meter and width of 4meter. Bu Tan wants to expand her field by size 8meter × 8meter"*
Teacher: *"Do you understand what the question means?"*

S-26: *"Understood, have to draw"*



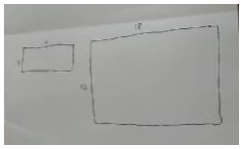
(S-26 illustrates a rice field after it is expanded)

S-8:



(S-8 illustrates an expanded rice field)

S-17:



(S-17 illustrates a rice field after it was expanded)

Teacher: *"Okay, S-17, why is the size became 18meter × 12meter?"*

S-17: *"You want to expand the rice field with a size of 8meter×8meter. So, from 10meter extended 8meter to 18meter and 4meter extended 8meter to 12meter"*

Teacher: *"Ohh.. What do the others think, which is the correct answer?"*

(Most of the students said the answer was S-8 or S-26)

From the conversation above, the S-17 had a mistake in understanding the word expansion. In simple terms, the S-17 thought that this expansion could be solved by addition. In fact, if the area is calculated, different results will be obtained. From this discussion, all students can understand the true broad meaning.

At the end of the activity, it is likely that students already know and understand the concepts of the perimeter of a square and a rectangle as described in the following interview fragment:

Teacher: *"Amir wants to replace the living room floor tiles with new tiles. The living room floor measures 10m×10m. What concept was used to determine the tiles Amir needed?".*

Students: *"To solve this problem, use the concept of a square area, so that it can be seen the number of tiles needed for the living room floor".*

In the last activity, researchers and students together drew conclusions about the activities that have been carried out in accordance with the learning goals to be completed at this fourth meeting.

DISCUSSION

A series of learning activities regarding the topic of quadrilaterals that the students went through consisted of four activities, namely the origami shape activity, the activity of find the properties game, the sulid activity (sticking the sticks), and the origami puzzle activity (sticking the papers). Each of these activities has its own purpose and is of course interrelated with one another. The following are the objectives of each activity: 1) origami shape is aimed at encouraging students to know the definition of quadrilaterals, 2) finding the properties game is aimed at supporting students to find out the properties of quadrilaterals, 3) sulid activity is aimed at supporting students to find the formula for the perimeter of a square and a rectangle, and 4) origami puzzle is aimed at assisting the students to find the formula for the area of a square and a rectangle. Giving activity sheets and student worksheets supports the learning process, where each activity presents the characteristics of RME (Subekti & Prahmana, 2021).

A series of activities through the learning process can assist students to understand the concept of quadrilaterals. This is in line with research carried by Puspasari, Zulkardi, and Somakim (2015) which suggests that a series of learning processes with the RME, in this case, the plotted Tangram, can support students to find the broad concept of polygons. In this study, a series of learning consisting of four activities with RME approach is designed and can support students to find the concepts of perimeter and area of squares and rectangles, and avoid students having misconception in understanding quadrilateral topics in detail. This is also in line with the results of research conducted by Afriansyah (2017) which reveals that a series of RME learning activities can create student-teacher candidates no longer mistaken in understanding the topic of fractions in detail. Therefore, the learning trajectory of a series of learning activities can help students to understand, develop, and solve problems in various materials (Prahmana, Kusumah, & Darhim, 2017; Confrey, et al., 2017; Putra & Vebrian, 2019; Nursyahidah, et al., 2020; Sunedi, 2021).

CONCLUSIONS

Through this research, researchers have succeeded in designing a series of learning activities using the RME approach to study quadrilaterals. The learning trajectory in the topic of quadrilaterals using the RME consists of four activities. Firstly, origami shape activity, which can evoke mathematical ideas of the definition of what a quadrilateral is and what types of quadrilaterals. Secondly, the activity of finding the properties of a quadrilateral which can make students come up with the properties of a square, rectangle, parallelogram, rhombus, kite, and trapezium. Thirdly, Sulid activity (stacking sticks), which can make students know how to formulate the perimeter of a square and rectangle and the application of the concepts of the perimeter of a square and rectangle in daily life. Lastly, origami puzzle activity which has mathematical ideas about how to form the

area of a square and rectangle as well as the application of the concept of area of a square and rectangle in daily life.

This research can provide contribution for other researchers to be able to design other activities with the same topic. Also, expanding this activity can be a good option if it can cover even better goals. Because what matters most is the contribution of our research to teachers and students in schools.

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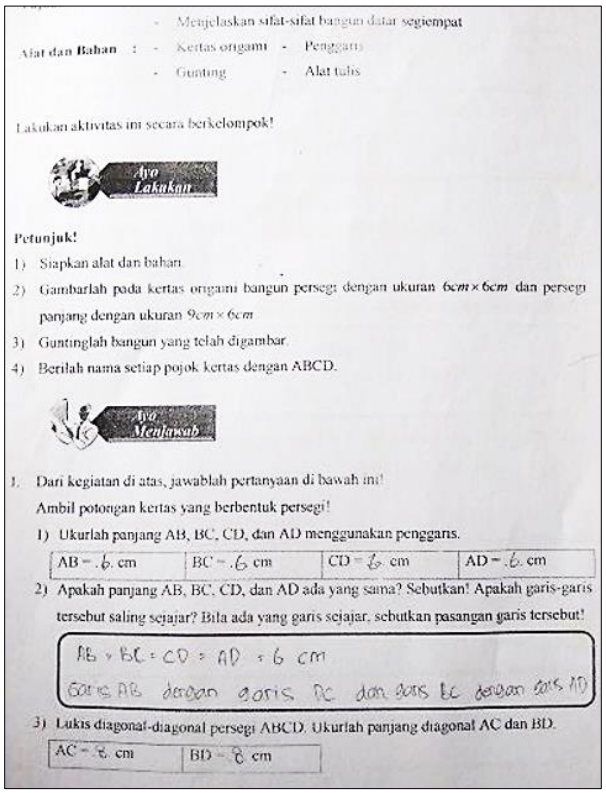
Appendix 1. English Transcript for Figure 6 Part 1.



- Menjelaskan sifat-sifat bangun datar segiempat

Alat dan Bahan : - Kertas origami - Penggaris
- Gunting - Alat tulis

Lakukan aktivitas ini secara berkelompok!

Ayo Lakukan

Petunjuk!
1) Siapkan alat dan bahan.
2) Gambarlah pada kertas origami bangun persegi dengan ukuran 6cm × 6cm dan persegi panjang dengan ukuran 9cm × 6cm
3) Guntinglah bangun yang telah digambar.
4) Berilah nama setiap pojok kertas dengan ABCD.

Ayo Menjawab

1. Dari kegiatan di atas, jawablah pertanyaan di bawah ini!
Ambil potongan kertas yang berbentuk persegi!
1) Ukurlah panjang AB, BC, CD, dan AD menggunakan penggaris.

AB = 6 cm	BC = 6 cm	CD = 6 cm	AD = 6 cm

2) Apakah panjang AB, BC, CD, dan AD ada yang sama? Sebutkan! Apakah garis-garis tersebut saling sejajar? Bila ada yang garis sejajar, sebutkan pasangan garis tersebut!

AB = BC = CD = AD = 6 cm
Garis AB dengan garis DC dan garis BC dengan garis AD

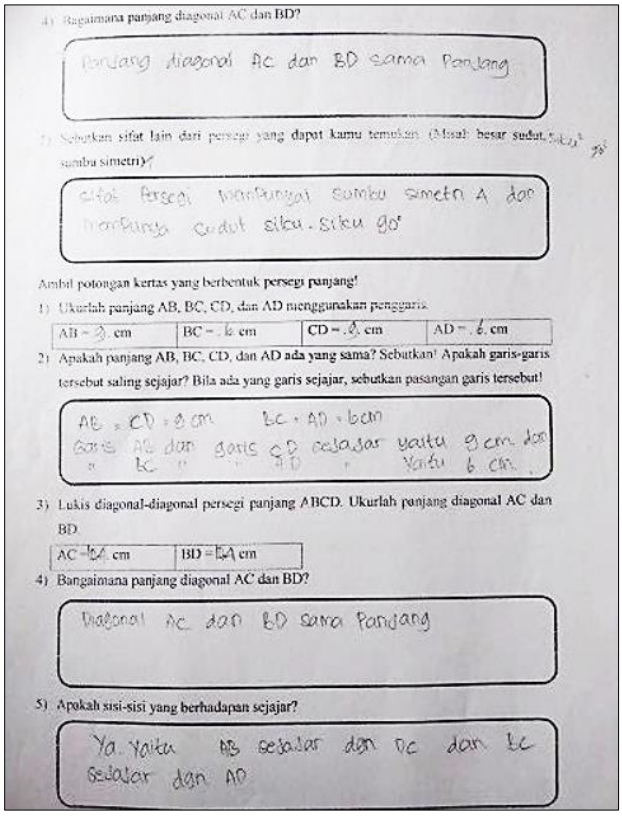
3) Lukis diagonal-diagonal persegi ABCD. Ukurlah panjang diagonal AC dan BD.

AC = 8 cm	BD = 8 cm

Tools and Materials: Origami Paper, Ruler, Scissors, Stationery
Do this activity in groups!
Let's do it
Instruction
1) Prepare tools and materials
2) Draw on origami paper a square with a size of 6 cm x 6 cm and a rectangle with a size of 9 cm x 9 cm
3) Cut out the shapes that have been drawn
4) Name each corner of the paper with ABCD
Let's Answer
1. From the activity above, answer the questions below!
Take a square piece of paper!
1) Measure the lengths of AB, BC, CD, and AD using a ruler
AB = 6 cm, BC = 6 cm, CD = 6 cm, AD = 6 cm
2) Are the lengths of AB, BC, CD, and AD the same? Mention! Are the lines parallel to each other? If there are parallel lines, name the pair of lines!
AB = BC = CD = AD = 6 cm
Line AB with line DC and line BC with line AD
3) Draw the diagonals of the square ABCD. Measure the length of the diagonals AC and BD!
AC = 8 cm, BD = 8 cm

Figure 6: Example of Student Work Results on Activity Sheet 2

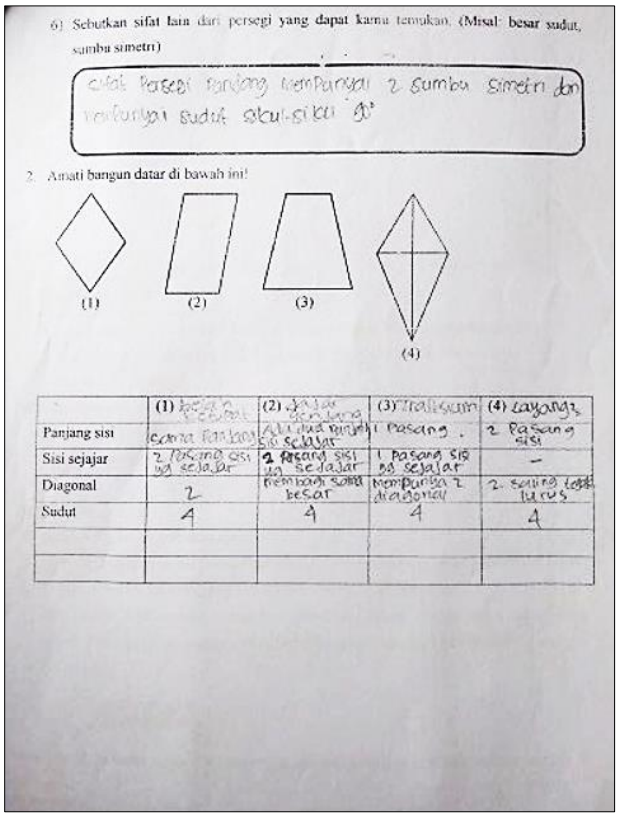
Appendix 2. English Transcript for Figure 6 Part 2.



4) What is the length of the diagonals AC and BD?
The lengths of the diagonals AC and BD are the same length
5) Mention other properties of rectangles that you can find (Example: a measure of angle, an axis of symmetry)
The property of a square has an axis of symmetry A and has a right angle of 90 degrees
Take a rectangular piece of paper!
1) Measure the lengths of AB, BC, CD, and AD using a ruler
AB = 9 cm, BC = 6 cm, CD = 9 cm, AD = 6 cm
2) Are the lengths of AB, BC, CD, and AD the same? Mention! Are the lines parallel to each other? If there are parallel lines, name the pair of lines!
AB = CD = 9 cm, BC = AD = 6 cm
The parallel lines AB and CD are 9 cm, and the lines BC and AD are parallel that is 6 cm
3) Draw the diagonals of the rectangle ABCD. Measure the lengths of the diagonals AC and BD.
AC = 9.4 cm, BD = 9.4 cm
4) What is the length of the diagonals AC and BD?
Diagonals AC and BD are the same lengths
5) Are opposite sides parallel?
Yes, i.e. AB is parallel to DC and BC is parallel to AD

Figure 6: Example of Student Work Results on Activity Sheet 2

Appendix 3. English Transcript for Figure 6 Part 3.

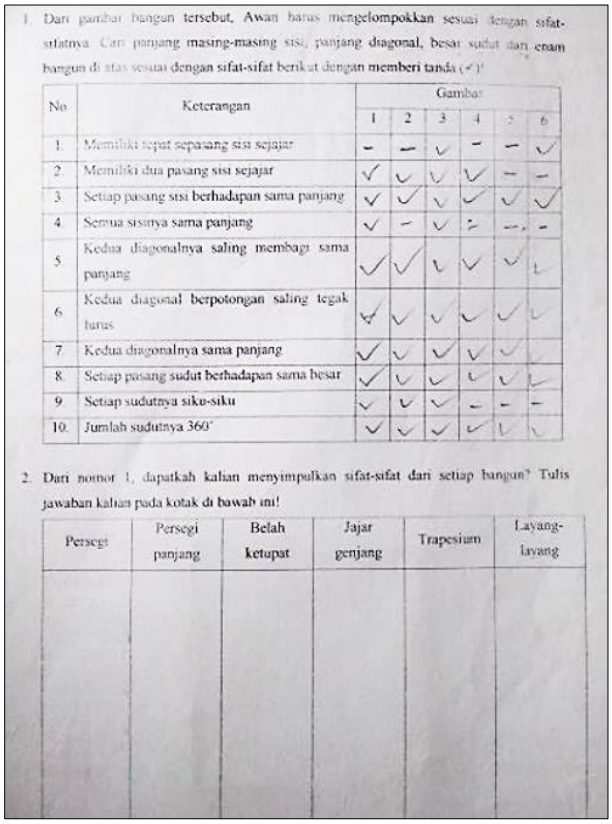


6) Mention other properties of squares that we can find (Example: a measure of angle, an axis of symmetry)
The property of a rectangle has 2 axes of symmetry and has a right angle of 90 degrees

2. Observe the flat shapes below!
(1) Rhombus; (2) parallelogram; (3) Trapezoid; (4) Kites
Side length:
(1) same length; (2) There are two lengths of parallel sides; (3) 1 pair; (4) 2 Pair side
Parallel sides:
(1) 2 pairs of parallel sides; (2) 2 pairs of parallel sides; (3) 1 pair of parallel sides; (4) –
Diagonals:
(1) 2; (2) divide equally; (3) has 2 diagonals; (4) 2 perpendicular to each other
Angle:
(1) 4; (2) 4; (3) 4; (4) 4

Figure 6: Example of Student Work Results on Activity Sheet 2

Appendix 4. English Transcript for Figure 7 Part 1.



1. Dari gambar bangun tersebut, Awan harus mengelompokkan sesuai dengan sifat-sifatnya. Cari panjang masing-masing sisi, panjang diagonal, besar sudut dari enam bangun di atas sesuai dengan sifat-sifat berikut dengan memberi tanda (✓)!

No	Keterangan	Gambar					
		1	2	3	4	5	6
1.	Memiliki sepat sepasang sisi sejajar	–	–	✓	–	–	✓
2.	Memiliki dua pasang sisi sejajar	✓	✓	✓	✓	–	–
3.	Setiap pasang sisi berhadapan sama panjang	✓	✓	✓	✓	✓	✓
4.	Semua sisinya sama panjang	✓	–	✓	–	–	–
5.	Kedua diagonalnya saling membagi sama panjang	✓	✓	✓	✓	✓	✓
6.	Kedua diagonal berpotongan saling tegak lurus	✓	✓	✓	✓	✓	✓
7.	Kedua diagonalnya sama panjang	✓	✓	✓	✓	✓	✓
8.	Setiap pasang sudut berhadapan sama besar	✓	✓	✓	✓	✓	✓
9.	Setiap sudutnya siku-siku	✓	✓	✓	–	–	–
10.	Jumlah sudutnya 360°	✓	✓	✓	✓	✓	✓

2. Dari nomor 1, dapatkah kalian menyimpulkan sifat-sifat dari setiap bangun? Tulis jawaban kalian pada kotak di bawah ini!

Persegi	Persegi panjang	Belah ketupat	Jajar genjang	Trapesium	Layang-layang

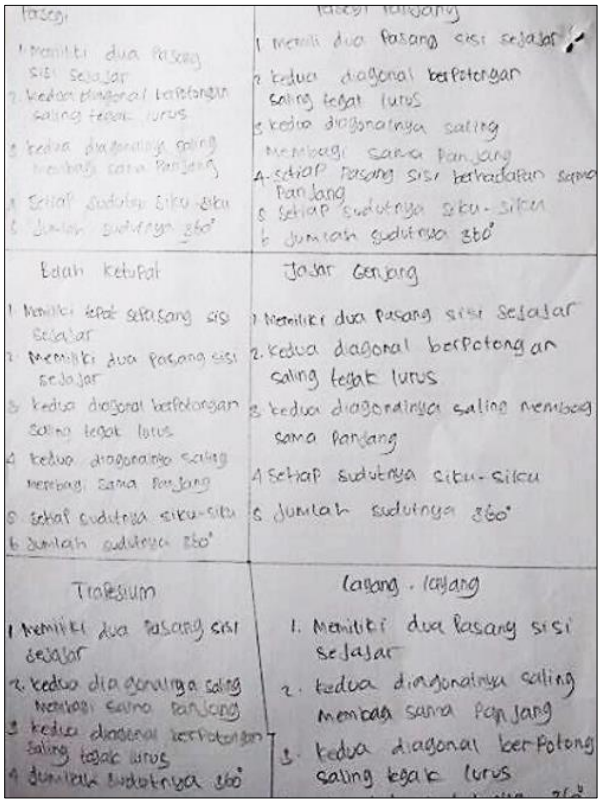
From the image of the wake, the cloud must be grouped according to its properties. Find the length of each side, the length of the diagonal, the measure of the angle, and the six shapes above according to the following properties by marking (√)!

No	Note	Figure
1	Has exactly one pair of parallel sides	
2	Has two pairs of parallel sides	
3	Each pair of opposite sides is the same length	
4	All sides are the same length	
5	The two diagonals bisect each other length	
6	The two diagonals are perpendicular to each other	
7	Both diagonals are the same length	
8	Each pair of opposite angles is equal	
9	Every angle is a right angle	
10	The sum of the angles is 360 degrees	

2. From number 1, can you conclude the properties of each shape? Write your answer in the box below!

Figure 7: Example of Student Worksheet Answers 2

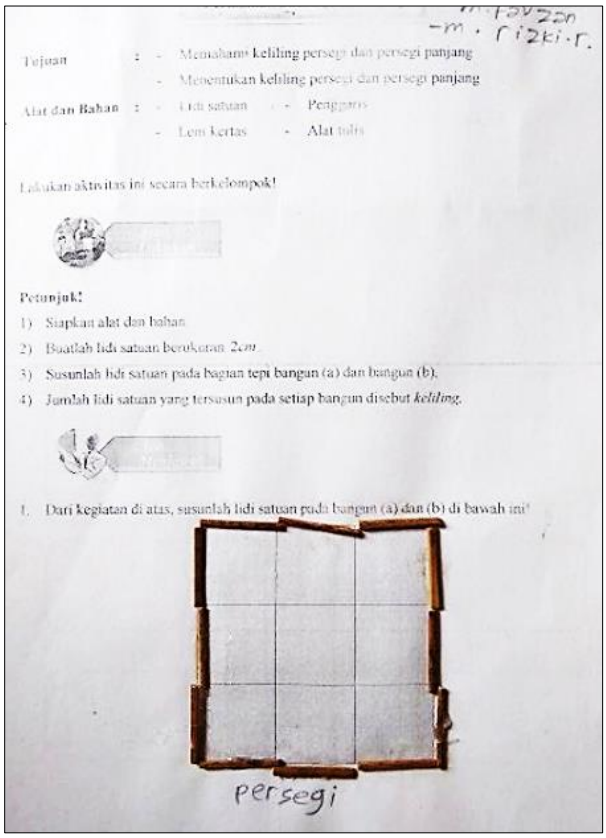
Appendix 5. English Transcript for Figure 7 Part 2.



Square 1. Has two pairs of parallel sides 2. The two diagonals are perpendicular to each other 3. Both diagonals bisect each other. Length 4. Every angle is a right angle 5. The sum of the angles is 360 degrees	Rectangle 1. Has two pairs of parallel sides 2. The two diagonals are perpendicular to each other 3. Both diagonals bisect each other. Length 4. Each pair of opposite sides is the same length 5. Every angle is a right angle 6. The sum of the angles is 360 degrees
Kite 1. Has exactly one pair of parallel sides 2. Has two pairs of parallel sides 3. The two diagonals are perpendicular to each other 4. Both diagonals bisect each other. Length 5. Every angle is a right angle 6. The sum of the angles is 360 degrees	Parallelogram 1. Has two pairs of parallel sides 2. The two diagonals are perpendicular to each other 3. Both diagonals bisect each other. length 4. Every angle is a right angle 5. The sum of the angles is 360 degrees
Trapezoid 1. Has two pairs of parallel sides 2. Both diagonals bisect each other. Length 3. The two diagonals are perpendicular to each other 4. The sum of the angles is 360 degrees	Kite 1. Has two pairs of parallel sides 2. Both diagonals bisect each other. Length 3. The two diagonals are perpendicular to each other

Figure 7: Example of Student Worksheet Answers 2

Appendix 6. English Transcript for Figure 10 Part 1.



Aim:
Understanding the perimeter of squares and rectangles
Determine the perimeter of a square and a rectangle
Tools and Materials: Sticks, Ruler, Paper glue, Stationery

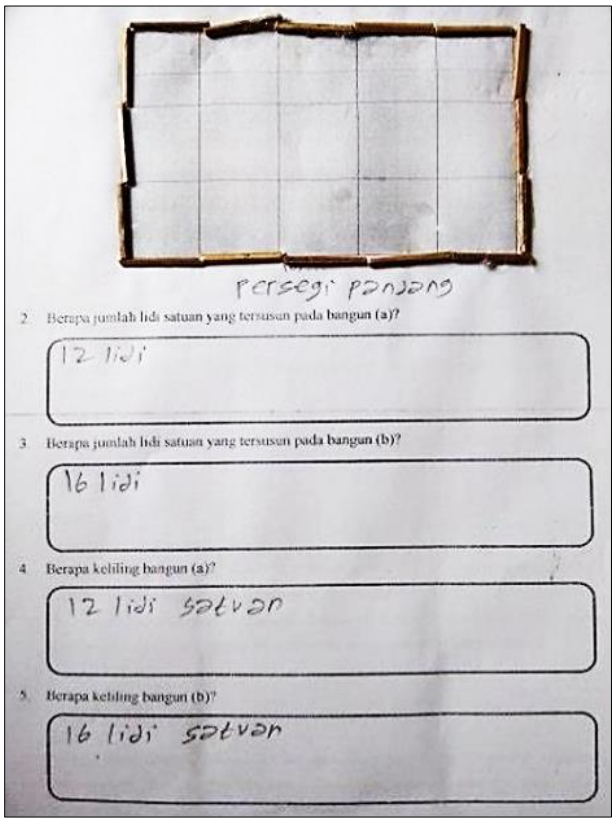
Do this activity in groups!
Let's do it
Instruction:
1) Prepare tools and materials
2) Make a stick measuring 2 cm
3) Arrange the unit sticks on the edges of the shape (a) and the shape (b)
4) The number of unit sticks arranged in each shape is called the circumference

Let's Answer
1. From the activity above, arrange the unit sticks in the shapes (a) and (b) below!

Rectangle

Figure 10: Example of Student Work Results on Activity Sheet 3

Appendix 7. English Transcript for Figure 10 Part 2.



Rectangle

2. How many unit sticks are arranged in shape (a)?
12 sticks

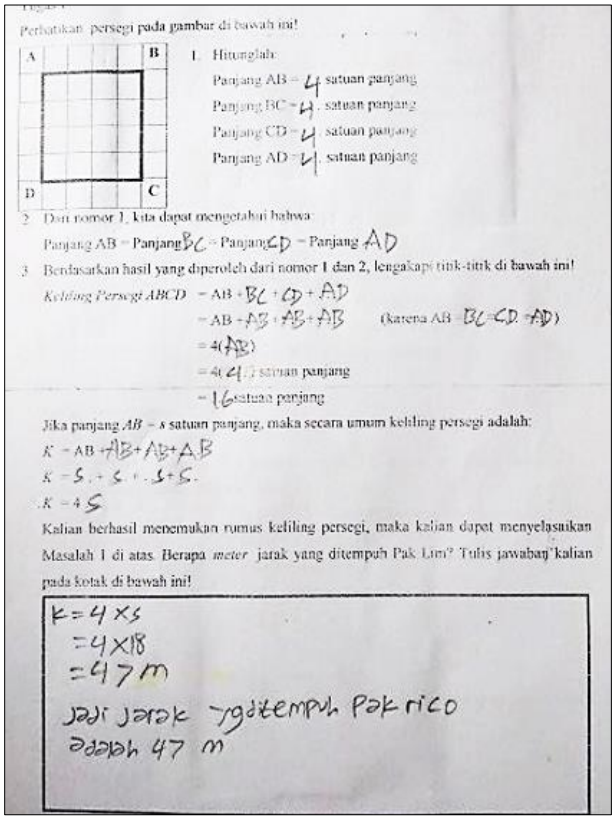
3. How many unit sticks are arranged in shape (b)?
16 sticks

4. What is the perimeter of the shape (a)?
12 sticks unit

5. What is the perimeter of the shape (b)?
16 sticks

Figure 10: Example of Student Work Results on Activity Sheet 3

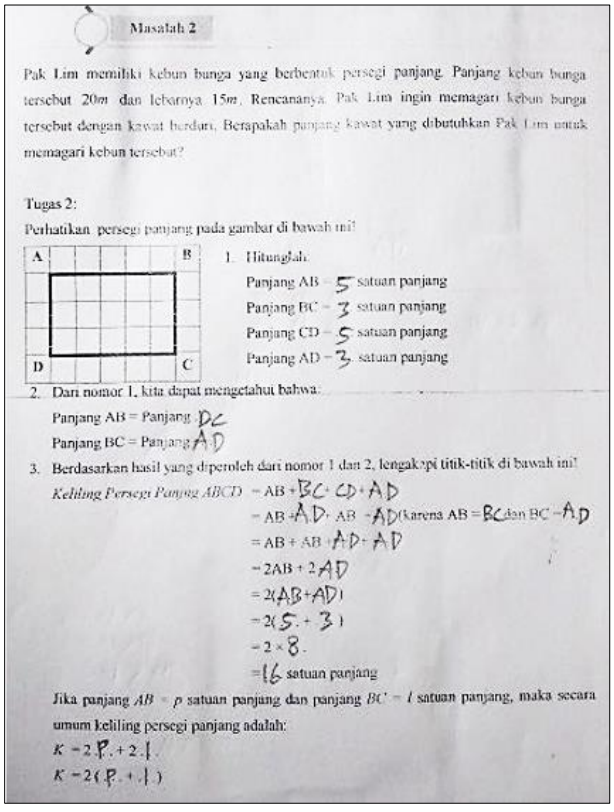
Appendix 8. English Transcript for Figure 11 Part 1.



Pay attention to the square in the image below!
1. Calculate:
Length AB = 4 units length
Length BC = 4 units length
Length CD = 4 units length
Length AD = 4 units length
2. From number 1, we can know that:
Length AB = Length BC = Length CD = Length AD
3. Based on the results obtained from numbers 1 and 2, complete the blanks below!
Perimeter of Square ABCD
= AB + BC + CD + AD
= AB + AB + AB + AB (because AB = BC = CD = AD)
= 4 (AB)
= 4 (4) units of length
= 16 units of length
If the length of AB = s units of length, then in general the perimeter of the square is:
K = AB + AB + AB + AB
K = s + s + s + s
K = 4s
You managed to find the formula for the perimeter of a square, then you can solve the problem above. How many meters did Mr. Lim travel? Write your answer in the box below!
K = 4 x s = 4 x 18 = 47 m
So, the distance that Mr. Rico travels is 47 m

Figure 11: Example of Student Worksheet Answers 3

Appendix 9. English Transcript for Figure 11 Part 2.



Masalah 2

Pak Lim memiliki kebun bunga yang berbentuk persegi panjang. Panjang kebun bunga tersebut 20*m* dan lebarnya 15*m*. Rencananya Pak Lim ingin memagari kebun bunga tersebut dengan kawat berduri. Berapakah panjang kawat yang dibutuhkan Pak Lim untuk memagari kebun tersebut?

Tugas 2:

Perhatikan persegi panjang pada gambar di bawah ini!

1. Hitunglah:
   Panjang AB = 5 satuan panjang
   Panjang BC = 3 satuan panjang
   Panjang CD = 5 satuan panjang
   Panjang AD = 3 satuan panjang
2. Dari nomor 1, kita dapat mengetahui bahwa:
   Panjang AB = Panjang DC
   Panjang BC = Panjang AD
3. Berdasarkan hasil yang diperoleh dari nomor 1 dan 2, lengkapi titik-titik di bawah ini!
   Keliling Persegi Panjang ABCD = AB + BC + CD + AD
   = AB + AD + AB + AD (karena AB = BC dan BC = AD)
   = AB + AB + AD + AD
   = 2AB + 2AD
   = 2(AB + AD)
   = 2(5 + 3)
   = 2 × 8
   = 16 satuan panjang

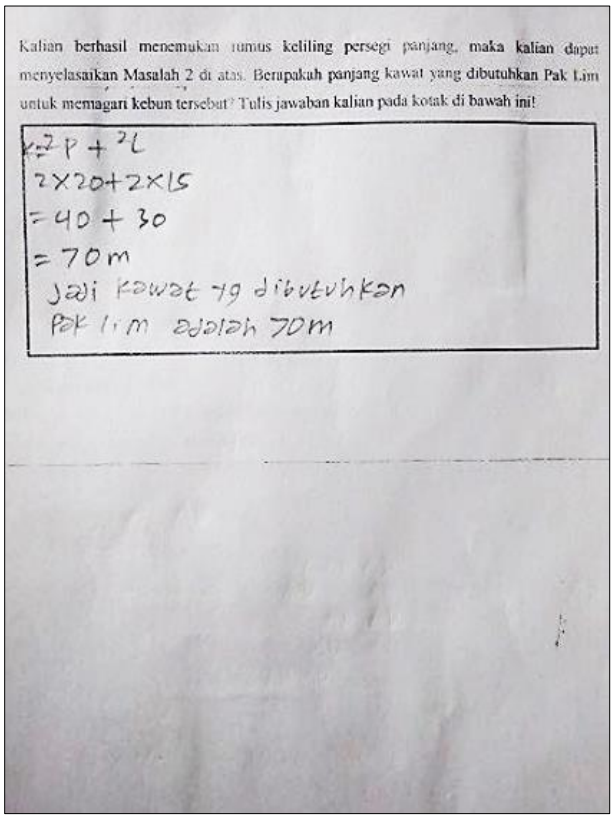
   Jika panjang *AB* = *p* satuan panjang dan panjang *BC* = *l* satuan panjang, maka secara umum keliling persegi panjang adalah:
   K = 2*p* + 2*l*
   K = 2(*p* + *l*)

Problem 2
Pak Lim owns a rectangular flower garden. The length of the flower garden is 20 m and the width is 15 m. The plan, Mr. Lim wanted to fence the flower garden with barbed wire. What length of wire does Mr. Lim need to fence the garden?

Task 2:
Pay attention to the rectangle in the image below!
1. Calculate:
Length AB = 5 units length
Length BC = 3 units length
Length CD = 5 units length
Length AD = 3 units length
2. From number 1, we can know that:
Length AB = Length DC
Length BC = Length AD
3. Based on the results obtained from numbers 1 and 2, complete the blanks below!
Perimeter of Rectangle ABCD
= AB + BC + CD + AD
= AB + AD + AB + AD (because AB = BC and BC = AD)
= 2AB + 2AD
= 2(AB + AD)
= 2 (5 + 3)
= 2 x 8
= 16 units of length
If the length of AB = p units of length and BC = l units of length, then in general the perimeter of the rectangle is:
K = 2p + 2l
K = 2 (p + l)

Figure 11: Example of Student Worksheet Answers 3

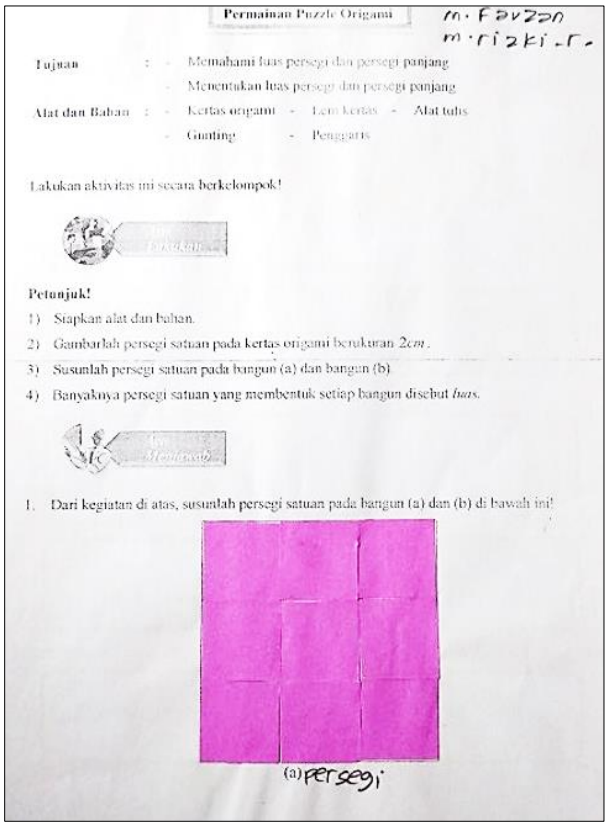
Appendix 10. English Transcript for Figure 11 Part 3.



You managed to find the formula for the perimeter of a rectangle, then you can solve problem 2 above. What length of wire does Mr. Lim need to fence the garden? Write your answer in the box below!
K = 2p + 2l
2 x 20 + 2 x 15
= 40 + 30
= 70 m
So, the wire needed Mr. Lim is 70 m

Figure 11: Example of Student Worksheet Answers 3

Appendix 11. English Transcript for Figure 14 Part 1.



Origami Puzzle Game

Aim:
Understanding the area of squares and rectangles
Determine the area of a square and a rectangle
Tools and Materials: Origami paper, Paper glue, Stationery, Scissors, Ruler

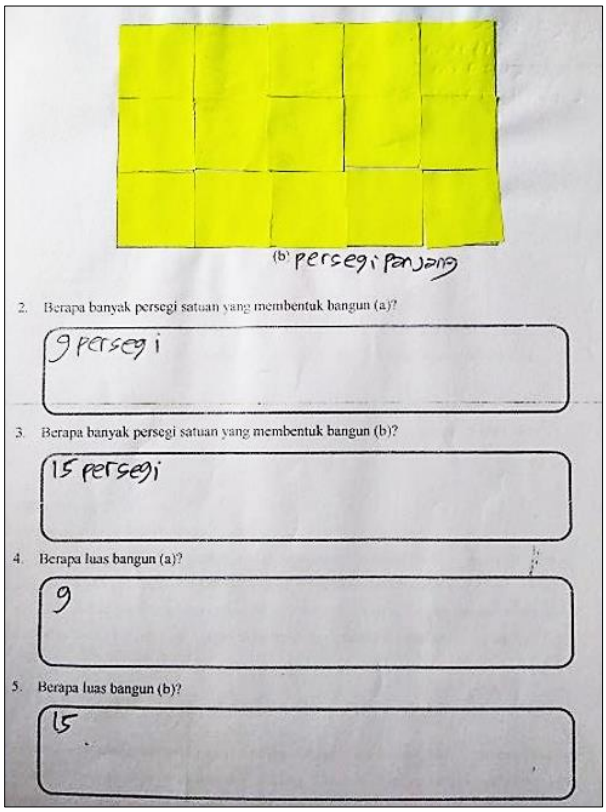
Do this activity in groups!
Let's do it
Instruction!
1) Prepare tools and materials
2) Draw a unit square on origami paper measuring 2 cm
3) Arrange the unit squares in shape (a) and shape (b)
4) The number of unit squares that make up each shape is called the area

Let's Answer
1. From the activity above, arrange the unit squares in the shapes (a) and (b) below!

(a) square

Figure 14: Example of Student Work Results on Activity Sheet 4

Appendix 12. English Transcript for Figure 14 Part 2.



(b) Rectangle

2. How many unit squares make up the shape (a)?
9 Square

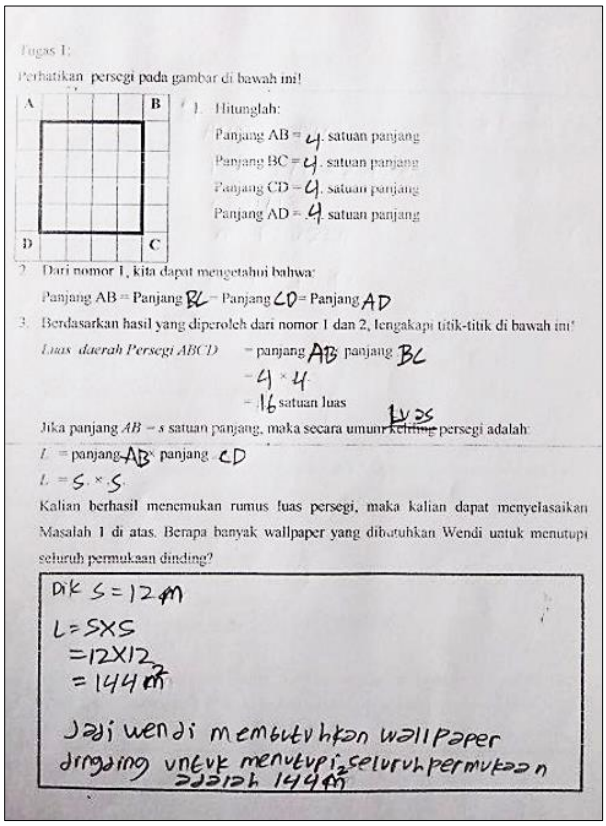
3. How many unit squares make up the shape (b)?
15 Square

4. What is the area of figure (a)?
9

5. What is the area of figure (b)?
15

Figure 14: Example of Student Work Results on Activity Sheet 4

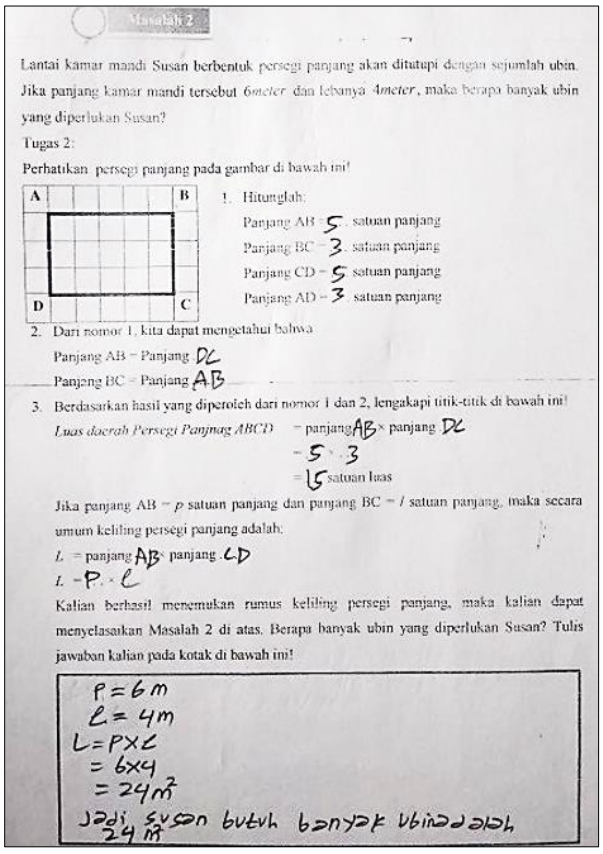
Appendix 13. English Transcript for Figure 15 Part 1.



Task 1:
Pay attention to the square in the image below!
1. Calculate:
Length AB = 4 units length
Length BC = 4 units length
Length CD = 4 units length
Length AD = 4 units length
2. From number 1, we can know that:
Length AB = Length BC = Length CD = Length AD
3. Based on the results obtained from numbers 1 and 2, complete the blanks below!
The area of Square ABCD
= Length AB x Length BC
= 4 x 4
= 16 units of area
If the length of AB = s units of length, then in general the area of the square is:
L = Length AB x Length CD
L = s x s
You managed to find the formula for the area of a square, then you can solve the problem 1 above. How much wallpaper does Wendi need to cover the entire wall surface?
Known: s = 12 m
L = s x s = 12 x 12 = 144 m^2
So, Wendi needs wallpaper to cover the entire surface is 144 m^2

Figure 15: Example of Student Worksheet Answers 4

Appendix 14. English Transcript for Figure 15 Part 2.



Masalah 2

Lantai kamar mandi Susan berbentuk persegi panjang akan ditutupi dengan sejumlah ubin. Jika panjang kamar mandi tersebut 6*meter* dan lebarnya 4*meter*, maka berapa banyak ubin yang diperlukan Susan?

Tugas 2:

Perhatikan persegi panjang pada gambar di bawah ini!

A B C D

1. Hitunglah:
   Panjang AB = 5 satuan panjang
   Panjang BC = 3 satuan panjang
   Panjang CD = 5 satuan panjang
   Panjang AD = 3 satuan panjang
2. Dari nomor 1, kita dapat mengetahui bahwa
   Panjang AB = Panjang DC
   Panjang BC = Panjang AB
3. Berdasarkan hasil yang diperoleh dari nomor 1 dan 2, lengkapi titik-titik di bawah ini!
   Luas daerah Persegi Panjang ABCD = panjang AB × panjang DC
   = 5 × 3
   = 15 satuan luas

   Jika panjang AB = *p* satuan panjang dan panjang BC = *l* satuan panjang, maka secara umum keliling persegi panjang adalah:
   L = panjang AB × panjang CD
   L = P × l

   Kalian berhasil menemukan rumus keliling persegi panjang, maka kalian dapat menyelasaikan Masalah 2 di atas. Berapa banyak ubin yang diperlukan Susan? Tulis jawaban kalian pada kotak di bawah ini!

P = 6 m
l = 4 m
L = P × l
= 6 × 4
= 24 m²
Jadi Susan butuh banyak ubin adalah 24 m²

Problem 2
Susan's rectangular bathroom floor will be covered with some tiles. If the length of the bathroom is 6 meters and the width is 4 meters, how many tiles does Susan need?

Task 2:
Pay attention to the rectangle in the image below!
1. Calculate:
Length AB = 5 units length
Length BC = 3 units length
Length CD = 5 units length
Length AD = 3 units length
2. From number 1, we can know that:
Length AB = Length DC
Length BC = Length AD
3. Based on the results obtained from numbers 1 and 2, complete the blanks below!
The area of Rectangle ABCD
= Length AB x Length DC
= 5 x 3
= 15 units of area
If the length of AB = p units of length and BC = l units of length, then in general the area of the rectangle is:
L = Length AB x Length CD
L = p x l
You managed to find the area of the rectangle, then you can solve Problem 2 above. How many tiles does Susan need? Write your answer in the box below!
p = 6 m
l = 4 m
L = p x l = 6 x 4 = 24 m^2
So, Susan need number of tiles is 24 m^2

Figure 15: Example of Student Worksheet Answers 4