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AN INVESTIGATION OF FAILURE SOLVING ILL-STRUCTURED PROBLEMS: A CASE STUDY

Ninik Mutianingsih[1], Lydia Lia Prayitno[2], Eko Sugandi[3], Sri Rahmawati Fitriatien[4], Agus Prasetyo Kurniawan[5]
[1,2,3,4]Mathematics Education, Faculty of Teacher Training and Science, Universitas PGRI Adi Buana Surabaya
[5]Mathematics Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sunan Ampel Surabaya

ninikmutia@unipasby.ac.id

Abstract

This research is a case study involving 63 students and choosing RZ as the subject. The aim is to describe the causes of failure of the RZ to solve the unstructured problem of rectangles. Ill-structured problems are problems with incomplete information that must be solved by students. The contribution that can be given is the geometry learning process that accustoms students to building relationships between the concept of the quadrilateral. This study is a qualitative study to describe the failure of RZ to solve ill-structured problems. Subjects are selected based on students who have failed to solve problems. The instrument used was a rectangular problem-solving test. The results showed that the subject was able to represent problems with their language. However, RZ failed to develop a suitable solution to the problem due to its partial mastery of the rectangular concept. RZ uses trial and error because it fails to associate the problem with the square concept which is the key to successful problem-solving. RZ was successful in the proving process because the calculation process was meaningless. Meanwhile, the monitoring and evaluation process failed to carry out RZ. Confusion RZ determines the final solution because the built solution does not qualify as a solution. This is where RZ fails to come up with a final solution. In this case, the teacher has a role to teach students to build relationships between concepts that can be used in problem-solving.
Keywords: rectangle; concept; failure.

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INTRODUCTION

An important point of education is to teach someone to think of being a reliable problem solver (NCTM, 2000; Shin, Jonassen, & McGee, 2003). Problem-solving is a complex activity be compared only to operating a component of the problem to get the solution. In the problem-solving involves cognitive components such as information statements from the problems (facts), concepts, rules, and principles (Jonassen, 1997).

Problem-solving is a process that illustrates the interaction from the ground up and from top to bottom involving the structure of knowledge that students already have started at the first time reading the problem text (Adanan, Adanan, & Herawan, 2020; Pape, 2004). Through the problem-solving process, the problem solver is directed towards determining the solution to the problem involving the knowledge it has. In fact, Mathematics classes provide the most consistent use of well-structured problems, which in line with problems in an everyday situation are involved many problems such as ill-structured (Hong, 1998). Ill-structured problems are a problem that comes from a problem situation in a particular context where more aspects of the problem situations are not described specifically, the description of the problem presented is also unclear, or the information not presented on the statement of the problem.

Furthermore, Hong (Hong, 1998) explained that students should dominate problem-solving skills in various types of problems, such as well-structured problems or ill-structured problems. When the problem solver is faced with ill-structured problems, the first step is to determine a problem in this problem's paper (Jonassen, 1997). This is because the problem in ill-structured problems allow to be presented explicit or concealed (Jonassen, 1997; Shin et al., 2003).

The first step that the problem solver can do is to specify important information or keywords from the context of the problem presented. Furthermore, the problem solver can build a representation according to the context of the problem situation (Avdiji, Elikan, Missonier, & Pigneur, 2018). From the representation, the problem solver is required to build justification or arguments that support the solution. This is because ill-structured problems allow considerable solutions, considerable path or considerable criteria for evaluating the solution (Avdiji et al., 2018; Ge & Land, 2003). If the resulting solution does not match the problem situation then the problem solver will have to represent the problem to find an alternate solution then retest it until it finds the solution that it felt is appropriate.

The stages of solving ill-structured problems are certainly different from the solving stages of well-structured problems. Obviously, this is influenced by the characteristics of different problems between the two. (Hong, 1998; Jonassen, 1997; Shin et al., 2003) It explains the stages of solving ill-structured problems consisting of (a) representation the problem, (b) generating solution, (c) justification, and (d) monitoring and evaluation. So in this study, researchers use the problem-solving stages as above.

In some studies, such as (Hong, 1998; Jonassen, 1997, 2003; Shin et al., 2003) students were given problems to be solved. These students tried to use problem-solving strategies, organized information, understanding the situation, evaluated and tested alternatives to see possible solutions to the problem. Problem-solving is required to be involved in the complexity of the problem situation, authentic, and open (Lizunkov, Politsinskaya, Gazin, & Oblast, 2020). Of course, this is can be enhancing the level of students' mathematical thinking and problem-solving skills in an everyday situations (Chi & Glaser, 1985; Subanji & Nusantara, 2016; Sukoriyanto, Nusantara, Subanji, & Chandra, 2016).

Studies on solving ill-structured problems as in astronomy simulations conducted by (Shin et al., 2003); in learning process by (Avdiji et al., 2018; Hong & Kim, 2016; Jonassen, 1997); Multimedia simulations (Hong, 1998), Problem-solving skills by (Chi & Glaser, 1985; Jonassen, 2003; Role et al., 2016). Out of some of these studies, there has been no research discussing the failure of solver problems in solving ill-structured problems. So, this study is important to know the cause of RZ fails when solving problems, especially on ill-structured problems about rectangular problem. In addition, it is important for teachers to look for solutions to overcome the failures that students experience so that their problem-solving skills are good. In addition, teachers must also adapt the learning process with their students' ability to overcome the failures experienced.

METHOD

This is a qualitative case study study to describe the failure of students to solve mathematical ill-structured problems, especially rectangular problems. This is qualitative study and focused case study that outlines an in-depth investigation, process, activity of an individual or group to achieve goals (Merriam, 2009; Miles & Huberman, 1994). The purpose this study is to explain a phenomenon in depth by way of collecting data as deep as possible, which shows the importance of the depth and detail of the data being studied. So, this study to see and describe students' failures in solving ill-structured problems, especially rectangular problems.

This study was conducted on class 11th students of SMA Negeri 15 Surabaya, East Java which involved 63 students. SMA Negeri 15 Surabaya was chosen because the school was an accredited school and had an acceleration program. Of the 63 students, one student who failed to solve the given problem was selected. Other considerations in the subject selection are based on students' answers, mathematical ability, and communication skills.

The problem used in this study was developed by researchers in consultation with high school mathematics teachers to obtain input. Students were given 45 minutes to solve ill-structured problems about the rectangle. The problem is given to students as follows.

> *"You are required to ask for a minimum of two proposals to change the length and width of a rectangle (in the percentages) so that the extent increases maximally but the perimeter is less than or equal to the perimeter of the initial rectangle. What do you think would be the maximum area according to the above conditions?"*

Semi-structured interview guidelines used researchers to discover of subject failure in solving ill-structured problems. Observation is used to collect students' mathematical skills data in 10th grade.

Researchers collected students' mathematical ability data on the rectangular studied in 10th grade. Before the study was conducted, researchers observed the mathematical learning process in the classroom to obtain information on the communication ability and mathematical skills of students. Students are given 45 minutes to submit proposals' changes to find problems' solutions. From the students' answers, researchers sort out the right and wrong answers. Then from the wrong answer, the researcher determines RZ as the subject of research. The consideration of choosing RZ is that it fails to provide a final answer, has moderate mathematics, and good communication skills.

Data analysis conducted researchers through four phases, (a) classify student answers based on right and wrong answers; (b) Based on the answer incorrectly selected one random subject with moderate mathematics capable and able to communicate well for interviews. The subject is RZ; (c) Present data to identify the cause of RZ's failure in solving the problem, and; (d) conclude. The failure indicators in solving ill-structured problems are based on table 1.

Table 1. Failure indicators in solving ill-structure problems

Phase	Indicator
Problem representation	Failed explain the problem with own language Failed to determine keywords Failed to interpret keywords
Generating solution	Failed to generate solution
Justification	Failed to provide proof of counting and argument Failed to use keywords in providing evidence and arguments
Monitoring & evaluation	Failed explain the results of solution evaluation and conformity

RESULTS AND DISCUSSION

RZ is a 16-year-old high school student of 11th grade sains from Surabaya, East Java. RZ has moderate mathematical abilities and can communicate well. The following describes the results of RZ's work and the research interviews with the subject based on the problem solving stage about rectangular problems.

a. Problem Representation

RZ begins to read the problem presented vocally, then describes the rectangle as a form of interpretation of the problem it reads. The subject presents a picture of a rectangle as in Figure 1.

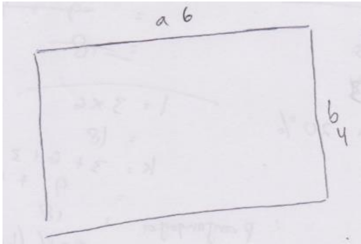


Figure 1. Interpreting problems

From the activity, RZ shows the subject is able to represent the problem of using his own language. In this case, RZ uses an image representation that is a rectangular image with a long symbolized by *a* and the width symbolized by *b*.
To discover other keywords from the given problem, researchers conduct interviews like the following interview.

Q : *Where are the important words of the problem?*
Ri : *(Subject re-read the problem given)*
I think it is important rectangular instead of waking the space, the rectangle here two dimensions and this change in length and width, eehh...the extent of increasing maximum, and its circumference is less than or equal to
Q : *Means how many keywords?*
Ri : *Hhhhm... The first length and width (the subject underlined the given problem), the rectangle, the area, and perimeter. It means there are four keywords.*

The above interview, shows that RZ assign four keywords that need to get noticed in the problem-solving process. These four keywords are (a) the length and width changes, (b) rectangles, (c) The extent of increasing maximum, and (d) the perimeter is less than or equal to. To emphasize what RZ is expressed is a keyword, RZ outlined it on the problem sheet as in Figure 2 below.

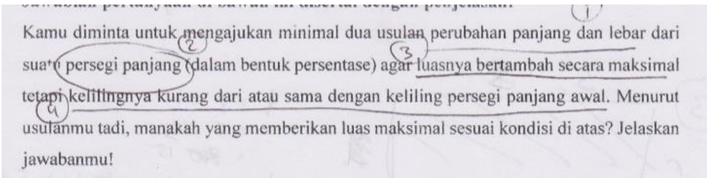

Kamu diminta untuk mengajukan minimal dua usulan perubahan panjang dan lebar dari suatu persegi panjang (dalam bentuk persentase) agar luasnya bertambah secara maksimal tetapi kelilingnya kurang dari atau sama dengan keliling persegi panjang awal. Menurut usulanmu tadi, manakah yang memberikan luas maksimal sesuai kondisi di atas? Jelaskan jawabanmu!

Figure 2. Underlining keywords

The next step is to interpret the specified keywords.

1st Keyword: Change length and width

Researchers interviewed RZ to discover its meaning as in the following quotation.

Q : What is the change in length and width?
Ri : Makes the length equally not the same as the initial but increased size
Q : Does it means?
Ri : Yes can be less or longer, so is the width or still can then be the percentage.

From the interview above, RZ has a change in the length and width of the rectangle as it makes the length and width different from the initial conditions. After further searching, RZ explains making different lengths and widths mean that new lengths can be less than initial lengths, new lengths can be increased from initial lengths, and new lengths are equal to initial lengths. This applies also to the new width of the rectangle.

2nd Keyword: Rectangle

RZ's usage of the rectangular concept is presented in the following interview quotations.

P : What kind of rectangle?
Ri : This is a rectangle (show to the picture on the answer sheet)
It.... (silence) to keep it hard to explain mam...
P : Tell me what you know?
Ri : Rectangular it in dimension two
hhmm…two-dimentional figure mam...
P : Then... What is the special characteristic of rectangular?
Ri : Has two equal sides, two parallel sides and two equal sides
Then, the same angle is also 90 degrees (pointing at the angle of the rectangle on the image)..

From the interview above, shows that RZ is able to explain the general characteristics of the rectangle, is in the second dimension, has two sides equal length and large angle of 90 degrees. RZ does not explain more detailed rectangles about folding symmetry, rotational symmetry, axis of symmetry, diagonals, and angles formed by the double diagonally intersect. When traced more about rectangular and square relationships, RZ is experiencing confusion and is unable to explain. This is because RZ only patlies on the sides of the rectangle without identifying other special traits. RZ reveals that during the learning process it receives, teachers rarely associate square and rectangular concepts.

To show the length concept of the rectangle, RZ using the symbol *a* and width using the symbol *b*. RZ raises the idea of using a certain number as the length and width of the rectangle as a substitute *a* and *b* as in Figure 1.

3th Keyword: Increasing maximum area

RZ's to interpret the increasing the maximum area presented in the following quotation.

P : The meaning increasing maximuma area?
Ri : I don't know mam…
(Long silence and seem anxious)
P : Just look at your answer?
Ri : (See the answer) should be a new area increase mam. The new area should be more than 24 mam.

From the interview above, RZ has confusion to explain the keyword's extent to increase the maximum. RZ was silent on explaining the researchers about the keyword and seemed anxious if the answers were given wrong. When the researcher pointed to the answer, RZ's confusion was slightly reduced, and RZ was able to explain the significance of the increase as the formation of a new area of more than 24. So the extent of increasing to the maximum means the extent increased from the initial area and increase as much as possible.

4th Keyword: The perimeter is less than or equal to

The meaning of RZ to the perimeter is less than or equal to the quote presented in the following interview.

P : *Meaning the perimeter is less than or equal to, should it be?*
Ri : *My proposal, the perimeter is less than or equal to and not more*
P : *Meaning?*
Ri : *No more than the initial perimeter 20*

With the previous usage, RZ gives the meaning that the new perimeter of the rectangle should be no more than 20. RZ no longer experienced confusion in the cause because it has had previous experience in the increase in the maximum.

b. Generating Solution

In generating the solution, RZ uses the number 6 as its length and 4 as the width of the rectangle. The reason RZ uses that number as a substitute for length and width as it likes the number. This indicates that RZ will do trial and error on the length and width of the rectangle so that it meets the specified perimeter requirements. The first proposal, RZ proposes a length of 6 and a width of 3 then determines its percentage as in Figure 3 below.

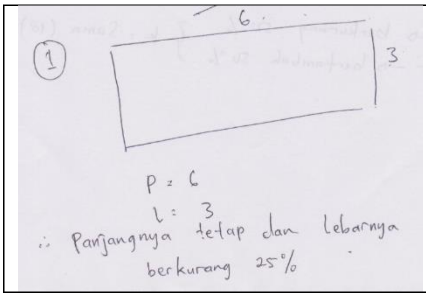
	Translate: p = length = 6 l = width = 3 Fixed length and width reduced by 25%

Figure 3. First proposal

While in the second proposal, RZ proposes a length of 6 and a width of 2 and then determines its percentage as in Figure 4.

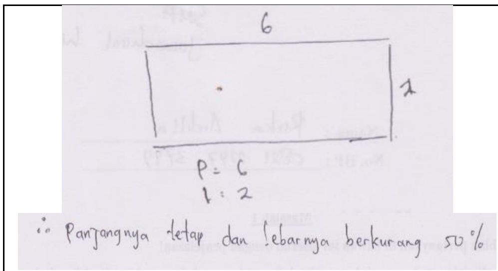
	Translate: p = length = 6 l = width = 2 Fixed length and width reduced by 50%

Figure 4. Second proposal

c. Justification

In the next step, RZ gives the given proposal justification by calculating the area and perimeter of the rectangle. Justification given RZ as the following Figure 5.

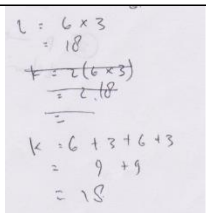
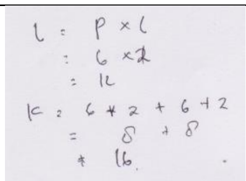
First proposal	
Second proposal	

Figure 5. RZ's justification of the proposal

Each proposed proposal, RZ begins by specifying the area of the rectangle followed by a perimeter.

d. Monitoring and Evaluation

RZ monitors and evaluates its propose based on its justification. The results of RZ's work in monitoring and evaluation in the following Figure 6.

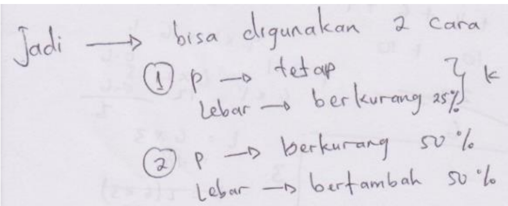
	Translate: So, we can use two methods 1. Length – fixed Width reduced by 25% 2. Length reduced by 50% Width increased by 50%

Figure 6. Monitoring and evaluation

To explore the understanding of the subject in concluding the results of monitoring and evaluation, researchers interviewed RZ like the following interview.

P : *So what is your conclusion?*
Ri : *In my proposal, my perimeter is less than or equal to and no more*
P : *It means?*
Ri : *This proposal (appoint the first proposal)*
Only 25% reduced and the second reduced to 50%
P : *Are you sure?*
Ri : *If answer both mam?*

P : *Meaning?*
Ri : *Can be used two different ways*

In the process of concluding, RZ also experienced confusion determining the most appropriate proposal to answer the problem. RZ interprets that every problem given should have a solution so that RZ concludes two ways that can be used as a solution.

RZ's ability to represent problems with his own language is the first step in the problem-solving process. This is because the problem representation is supposed to be making sense for the problem solver so it supports the problem solving process done (Hoogland, de Koning, Bakker, Pepin, & Gravemeijer, 2018; Hoogland & Pepin, 2016), (Adanan et al., 2020). A problem representation is a key component in the problem-solving process that helps students (Avdiji et al., 2018; Bal, 2014; Boonen, Reed, Schoonenboom, & Jolles, 2016; Goldin, 1998; Stylianou & Silver, 2004; Xin, Jitendra, & Buchman, 2005). The researcher agreed that the problem representation is a key component in solving mathematical problems, especially verbal problems whose involves representations, both symbolically and visually.

The determination of the keywords that RZ set helped him to represent the problem. Keywords are a form of understanding of the subject to the problems presented (Adanan et al., 2020; Hegarty, Mayer, & Monk, 1995; Stylianou & Silver, 2004). The emphasis of the subject by underlining is one of the learning strategies of a repeating strategy. Arends reveals through an underlined process giving students the opportunity to connect new information to problems with existing knowledge. In this case, enhancing creative thinking skill is the one important component in problem solving (Palupi, Subiyantoro, Triyanto, & Rukayah, 2020). The steps students performed to represent the problem with attention to information relevant to the problem and present problems in concrete objects (Mairing, 2017; Xin et al., 2005). In this case, RZ used using a drawing picture.

There are many ways for students to solve problems, one of which raises ideas, such as length and width. Such as using numbers to declare the length and width of a rectangle (Anwar, Yuwono, As'ari, Sisworo, & Rahmawati, 2016) or use the price of a particular item (Abdillah, Nusantara, Subanji, Susanto, & Abadyo, 2016) to help solve the problem. The idea that RZ developed is not used properly in generating solutions. This is because the solution built by RZ is the result of trial and error which is then justification. Whereas submitting proposals is one of the right methods to solve the problem (Chi & Glaser, 1985; Debrenti, 2015) in particular in this study.

The trial and error of RZ because the subject has no mastery of the concept of a square. In fact, mastery of concept is a key in problem solving process. Students who have good concept mastery are able to connect between concepts that have been studied with problems that will be solved (Anwar et al., 2016; Subanji & Nusantara, 2016). RZ's failures are the same as the research (Abdillah et al., 2016; Debrenti, 2015) which states that failure in establishing a relationship between knowledge is one of problem solving constraints (Debrenti, 2015), particularly ill-structured problems.

The justification made by RZ in determining the perimeter and area of the rectangle is not a barrier. From the investigative outcome, RZ knows how to calculate the perimeter and area of the rectangle but is unable to explain the meaning of those concept clearly.

RZ fails in monitoring and evaluation of the right solution. Consequently, the final solution provided by RZ does not match the desired situation of the problem. Self-check abilities involve self-awareness to determine the final solution of the problem solving process (Debrenti, 2015). It is reinforced (Debrenti, 2015; Ijirana & Nadjamuddin, 2019) who expressed metacognitively students can be developed through a problem solving process.

From the results of RZ's work above, it shows that in the process of solving problems RZ works based on alteration (Sukoriyanto et al., 2016; Swastika, Nusantara, Subanji, & Irawati, 2020). This shows that RZ has a good self-regulated in problem solving process. But this does not guarantee that the subject is able to find the right solution (Ijirana & Nadjamuddin, 2019; Lim, Jaya, Jalil, & Saad, 2020). So, students can improve their ability to formalize and generalize understanding of problems by finding mathematical structures in problems that are appropriate to real-life contexts (Prayitno, Purwanto, Subanji, & Susiswo, 2018), then determining alternative solutions, implementing them, and finding appropriate solutions. (J. Hong & Kim, 2016; Liang, Tsai, Chang, Lin, & Su, 2016).

In the learning process it is important for teachers to associate a concept with another mathematical concept (Palupi et al., 2020) using problem-based learning (Lizunkov et al., 2020). The goal is to have students' mastery over the mathematical concept integral. In this study students were required to relate between rectangular and square concepts to find solution the problems.

CONCLUSION

From the results and discussion above, RZ has failed to build solutions as well as monitoring and evaluation of proposed solutions. Based on the search results of researchers this is due to the mastery of a partial rectangular concept so that RZ only do a trial and error in finding a solution. In fact, mastery of concept is a key in problem-solving process. Consequently the solution provided is not according to the wishes of the problem. For that, more research needs to be done by choosing a subject that has a good quadrilent concept mastery.

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