Conceptual and procedural knowledge of junior high school students through realistic mathematics education (RME) approach

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Abstract. Mathematics learning that provides the ready-made concepts and procedures without involving students in re-invention the concepts. RME approach is a solution for upgrading the students’ competency in reconstructing the concepts and creating the procedures to solve the mathematical problems. This research aims to identify the students’ conceptual and procedural knowledge through the RME approach based on the students’ ability level. This study used a mixed-method and involved the Year 7 students as the sample. The data were analyzed using percentage and explained descriptively. The results indicated that the percentage of the procedural knowledge of the high and medium-achieving students was 80%, categorized as very good, while the percentage of the low-achieving students was 42.8% (adequate). The conceptual knowledge of the high, medium and low-achieving students was very good (84%), good (72.7%) and adequate (42.8%). The conceptual knowledge of the low-achieving students was higher than their procedural knowledge by 2.8%. The results showed that the medium-achieving students tended to be varied and flexible in applying their ideas to solve the procedural problems, meanwhile the high-achieving students inclined to memorize the concept and use a formula in solving the problems.

1. Introduction
Mathematics curriculum for high schools in Indonesia emphasizes mathematics competency on understanding problems by involving the concepts and applying them based on the correct algorithm. It becomes the main point to be mastered by students in solving mathematical problems [1]. In solving the mathematical problems, the students need both conceptual and procedural knowledge to comprehend the problems by linking the concepts and implementing them based on the proper algorithm. The conceptual knowledge is the basis of connected networks to link the discrete pieces of information. Procedural knowledge refers to the steps of activities conducted, including rules and algorithms [2]. Direct mathematics learning that provides the formulas without connecting them to the students’ real-life might lead them to comprehend the questions merely in symbols and mathematical language. It contributes to the lack of students’ mathematical understanding in solving the contextual problems, as indicated by the PISA result in 2015. Indonesia was ranked 63 out of 70 countries because Indonesian students’ mathematics literacy was only at level 2.

Junior high school students are at the formal operational stage, and they could not think logically without the presence of concrete objects. Teachers have to develop the students’ conceptual and procedural knowledge by giving mathematical problems that are closed to their life. Process-oriented
learning was necessary so that the students could discover the concepts through the activities in multiple situations and realistic problems. For example, providing the learning tools and connecting them to real life. This type of learning is the characteristics of Realistic Mathematics Education (RME) approach.

RME approach is the learning model employing reality and environment that is easily understood by the students to facilitate the mathematics learning process. The RME conceptualizes mathematics as human activities in their life, instead of passively accepting mathematics as the ready-made objects [3]. Besides, the realistic approach helps the students to change contextual problems into mathematical language with symbols through real problems. Then, they solve the problems by correct procedures and stages. Therefore, the RME is one of the appropriate models that teachers should apply to help students re-discover the concepts and create the procedures to solve the mathematical problems [4]. Also, a research finding reported that the students’ procedural knowledge is higher than their conceptual knowledge when using RME [5]. Thus, this study aims to analyze the conceptual and procedural abilities of the high, medium and low-achieving students in solving mathematical problems through the RME approach.

2. Method
This research used a mixed-method with the explanatory sequential strategy. The data were first collected and analyzed quantitatively, then followed by qualitative data collection and analysis. The sample selection employed a random sampling technique, and the subjects were selected based on the students’ answers. This research was conducted in one of the junior high schools in Banda Aceh, Indonesia. The participants were 30 Year 7 students classified into the high, medium and low-achieving groups based on the analysis of the students’ initial mathematics performance. The data were obtained from the test concerning the students’ conceptual and procedural knowledge. The test consisted of three problems assessing the students’ conceptual knowledge and another three for their procedural knowledge. The conceptual and procedural knowledge indicators used in designing the test referred to the indicators stated by [6]. The students’ test scores were presented in percentage, and the classification is presented as follows.

| Percentage     | Criteria   |
|----------------|------------|
| 80 < Percentage ≤ 100 | Very Good  |
| 60 < Percentage ≤ 80  | Good       |
| 40 < Percentage ≤ 60  | Adequate   |
| 20 < Percentage ≤ 40  | Poor       |
| 0 < Percentage ≤ 20   | Very Poor  |

The qualitative data collection involved the semi-structured interview with some students. It was conducted after the researchers had given the students’ test results. The data in this mixed-method study were analyzed by exploring the outlier-outlie [7], namely analyzing the quantitative data based on the students’ test results in the form of percentages or numbers and analyzing the qualitative data to gain the detailed information.

3. Result and discussion
The students' conceptual and procedural knowledge were analyzed by the RME approach in four meetings. The RME approach was implemented based on the Ice Berg’s stages, designed and developed through the lessons plan. The test was administered in the fifth meeting, and the semi-structured interview was conducted in the following meeting. The test consisted of problems that measure the students’ conceptual and procedural knowledge through the RME approach.
3.1 The students’ procedural knowledge

The students’ answers in solving the problems concerning the procedural knowledge were described in Table 2.

Table 2. The percentage of the students’ procedural knowledge based on the indicators.

| No | Indicator                                           | Max score | High 5 students | Medium 18 students | Low 7 students |
|----|-----------------------------------------------------|-----------|-----------------|--------------------|---------------|
|    |                                                     |           | Mean %          | Mean %             | Mean %        |
| 1  | Using algorithm generally                          | 20        | 19              | 17.22              | 13.6          |
|    |                                                     |           |                 |                    | 68            |
| 2  | Using the procedure properly, flexibly, and efficiently | 20        | 14              | 15.7               | 12.86         |
|    |                                                     |           |                 |                    | 64            |
| 3  | Using mathematical procedure correctly             | 10        | 9.6             | 8.44               | 4.7           |
|    |                                                     |           |                 |                    | 47            |

The procedural knowledge of the high and medium-achieving groups was very good. However, based on the procedural knowledge indicators, the high-achieving students tended to memorize the mathematical problem-solving as described in Figure 1.

![Figure 1](image1.png)

**Figure 1.** The answer of a high-achieving student for the procedural indicators.

Teacher : Could you explain how you determine the sum of the money?
Student : The price of three pieces was 2,000, first find the unit price, that is 66.67, I round it to 667, then multiply it by the number of students, 81 x 2, as each gets 2, the result is 162. Then, we multiply 667 x 162 = IDR 108,054
Teacher : How do we pay 54? The smallest nominal money was IDR 500
Student : In that case, we round it to IDR 108,000.

Based on the interview results with some high achieving students, they did not use the comparison concept. The students could solve the problem but did not understand it as they tended to memorize the procedure without comprehending the problem.

The medium-achieving students had some ways to solve the procedural problem, as presented in one of the students’ answers in Figure 2.

![Figure 2](image2.png)

**Figure 2.** The answer of a medium-achieving student for the procedural indicators.
Teacher : Could you explain how you solve the problem?
Student : First, we find how many pieces of cake we should buy, that is 162. Then, we divide by three. Then, 54 is multiplied by 2,000, equal to IDR 108,000.
Teacher : Why do you divide it by three?
Student : Because it is given that three pieces of cake are 2,000.

The test and interview results indicated that the medium-achieving students solved the problem slowly, and they generally used the easy ways to do it. This can be said that students in medium-achieving students are having a good intuitive in analyzing answers to mathematical problems. Polya asserts that the students with a good intuitive understanding have the mindset of solving a problem by estimating the correct answer undoubtedly before analyzing it analytically [8]. Furthermore, the procedural knowledge of the low achieving students was poor (less than 60%), as indicated on the students’ answers and interview. Figure 3 displays the common mistakes made by this group of students.

Figure 3. The answer of a low-achieving student for the procedural indicators.

Figure 3 showed that the low-achieving students understood the question, but they could not solve the multiplication as they did not understand it.
Teacher : How do we know the number of candies for each kid if there are 16 kids?
Student : 112 is multiplied by 16
Teacher : Why didn’t you write the result?
Student : I do not understand the method of long division.
Teacher : In this case, your correct answer may be wrong due to the multiplication.
Student : (silent)

Lack of students’ mathematical basic knowledge affected their ability to solve the problems correctly, as Van de Walle explains that the concepts in mathematical learning are interrelated. The students should understand a concept before understanding the other concepts [9].

3.2 The students’ conceptual knowledge
The students’ answers in solving the problem concerning the conceptual knowledge indicators were described in Table 3.

| No | Indicator                                      | Max score | High 5 students | Medium 18 students | Low 7 students |
|----|-----------------------------------------------|-----------|-----------------|-------------------|--------------|
| 3  | Presenting concepts into various forms of mathematical representation | 10        | 8               | 6.3               | 3.6          | 74 % | 64 % | 35.7 % |
| 4  | Re-stating the verbal concepts learned        | 20        | 18              | 15                | 10.7         | 95 % | 75 % | 53.5 % |
| 5  | Applying the concepts provided in the algorithm | 20        | 16              | 9.2               | 4.3          | 80 % | 46 % | 21 %  |
The high and medium-achieving students solved the conceptual problems well. It is in line with a research finding describing that the RME approach could help students to build the concept independently in solving mathematical problems [10]. However, some students in the three groups had difficulties in the indicator of presenting the concepts into various forms of mathematical representation. They had problems in drawing the graph. The answer and interview results of the medium-achieving students are described as follows.

![Graph Image]

**Figure 4.** The answer of a medium-achieving student for the conceptual indicators.

Teacher : How is the graph? Is it correct?
Student : We can see $x = 8$ and $y = 3$, we write it like this, then $x = 6$ and $y = 4$, we determine it and so on.
Teacher : Observe the number in the x-axis, is it in order?
Student : No, the smallest number should come first
Teacher : Yes, why did you draw the picture like this?
Student : I thought, we determine the coordinate based on the order in the column.

This problem appeared due to the lack of conceptual understanding in drawing the graph in elementary schools. According to Glynn, the high school students have problems in formalizing the word problems into mathematical models because they have just started their concrete to abstract learning [11]. Besides, the mathematical learning at elementary and high schools should be meaningful, by providing the learning tools and connecting the concepts to the students' real-life [12]. Based on data analysis low ability students are better able to understand the concept of learning through the RME approach. It was in line with a research finding reporting that the RME approach improved the students’ conceptual understanding [13].

**4. Conclusion**

The mean score of the students in the three groups in answering the problems based on the conceptual and procedural indicators has been described. The procedural knowledge of the high and medium-achieving students was higher than their conceptual knowledge. However, the conceptual knowledge of the low-achieving students was higher than their procedural knowledge by 2.8%. Therefore, the RME approach influenced the low-achieving students. Based on the students’ answers in solving the problems concerning the procedural knowledge indicators, the medium-achieving students’ answers were varied. They were flexible in employing ideas to solve the procedural problems. On the other hand, the high-achieving students tended to memorize the concept and solve the problem using formulas. The medium-achieving students had a good intuitive understanding, by using good analysis in solving problems.

The low-achieving students had a lack of mathematical problem-solving ability due to their lack of motivation. In addition, the lack of the students’ basic mathematical understanding (such as long division and decimal multiplication) influenced their ability to solve the problems correctly.
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