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How Does Realistic Mathematics Education (RME) Improve Students' Mathematics Cognitive Achievement?

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ABSTRACT

Some previous research has reported the effectiveness of RME in improving students' problem solving ability and cognitive achievement. This quasi experimental research, therefore, aimed to investigate the difference in students' mathematics cognitive achievement after implementing RME and conventional learning. The controlled treatment consisted of mathematics learning with RME equipped with snake and ladder board game and conventional learning. Instrument measuring students' cognitive achievement was developed by the researcher and validated by some experts prior to the research. The results of the t-test confirmed the difference in students' cognitive achievement both of the experimental and control group. The students who were taught with RME achieved better than the students who were involved in conventional learning. This research finding has suggested that it is important for teachers to empower students' intellectual ability through RME and games in order that meaningful and contextual learning can be generated. It is recommended that future research will explore the effect of RME on students' attitude, problem-solving ability, learning interest, or other variables related to mathematics learning.

Keywords: realistic mathematics learning (RME), snake and ladder, conventional, cognitive achievement

INTRODUCTION

Mathematics is a compulsory subject taught at all levels of education from elementary level to higher level of education. Mathematics has become a basic capital for life, particularly for solving everyday problems. Mathematics has systematic logic, following regular, and specific orders. Learning mathematics makes our brain used to solving problems systematically. As a result, in the real world, we can easily provide solutions to every problem. Besides, mathematics also helps us learn other sciences including economics, accounting, chemistry, physics, and etc. If students face difficulties in learning mathematics, it can also affect them in other calculation subjects. It is necessary to learn mathematics since it develops students' higher order of thinking. In fact, in the reality, students are afraid of learning mathematics and most of the time avoid it. This suggests that teachers need to do some reflection on mathematics learning to make it more interesting and fun for students.

Many students feel afraid of and face difficulties in studying mathematics. Commonly, mathematics problems are made so complicated that it is difficult for the students to solve them. This condition then impacts in poor students' cognitive achievement. Similarly, Veloo & Zubainur (2014) state that the anxiety level of the majority of Indonesian students increases if they are enrolled in a mathematics class. Mathematics learning in Indonesia is still below average if it is compared to mathematics learning in developing countries in Asia such as China, Singapore, and Malaysia. For the past few years, it has been proved many times that China has surpassed other western countries in terms of their international scaled mathematics achievement, such as in PISA and *International Mathematical Olympiads* (IMO) (Fan & Zhu, 2004; IMO, 2017).

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Contribution of this paper to the literature

- Various learning media that are often used by students in everyday life can be utilized and improved quality in learning through the creativity of teachers, such snakes and ladder on geometry.
- The RME approach through snake and ladder on geometry enhances students' cognitive achievement, because students are empowered to solve real problems in daily life and minimize misconceptions.
- The RME approach becomes one of the most effective approaches in fostering motivation, self-confidence, problem-solving skills, and reasoning that impact on improving cognitive achievement.

Leasa & Corebima (2017) revealed that learning process in Ambon has been focusing more on promoting low level cognitive aspect. Besides, anonymous learning was still dominant which means that learning involved no particular model design or strategies. The results of an observation conducted to some junior high schools (SMPs) in Ambon have confirmed that mathematics learning in general was still teacher-centred, mechanical, and conventional. Learning was oriented on achieving the curriculum target so that it ignored the effort to implant in-depth mathematics concepts on students. The teacher would be more likely to teach all the materials merely to fulfil his/her administrative responsibility and as a result disregard students' need for knowledge. Some factors may possibly influence students' low mathematics achievement. They include the execution of traditional mathematics learning, students' failure, and students' lack of interest in mathematics (Tella, 2007).

The results of preliminary observation and interviews conducted to mathematics teachers in Ambon indicated that most of the students assumed that mathematics was difficult and boring. The materials covered complicated formulas and examples of solving mathematics problems. The students, thus, were unable to develop themselves since they were not given any opportunity to deliver their ideas and figure out mathematics concepts on their own.

Mechanical mathematics learning can be made much easier and more fun. Mathematics learning is supposedly designed to provide continuous pleasure and comfort for students without imposing anything to them. Students need to have a willingness to learn; therefore, learning approach should maintain the desire. The easiness of learning can be experienced if learning contents and contexts are related to students' daily activities. Realistic Mathematics Education (RME) is one of the approaches which addresses problems caused by traditional and abstract mathematics learning (Bray & Tangney, 2015). RME was originated from Freudenthal's ideas in 1971 which said that mathematics was a part of humans' life (Freudenthal, 1971). According to him, students should be given an opportunity to re-discover mathematics by managing and processing a real-world situation or a mathematical relationship as well as a process which is substantial for them.

Using unique and amusing learning media can be one of the ways to empower and strengthen mathematics concepts. In this research, snake and ladder board game was developed to help students answer mathematics problems related to their lives. Snake and ladder is a game that can be used as a learning medium. This game appears visually as a pattern on a board which consists of boxes. These boxes contain materials to learn. In mathematics learning, this game provides refreshment for students' cognitive ability so that their boredom level can be decreased. Garris, Ahlers, & Driskell (2002) points out that games-based learning can help promote three things, (1) students' motor skills development, (2) students' strategic knowledge development, and (3) students' attitude.

Some previous related research has revealed RME functions in mathematics learning. The studies have also unveiled the relationship between critical thinking and cognitive achievement resulted from particular learning model or strategy. Zubainur, Vello, & Khalid (2015) examined the effect of RME on cognitive achievement of elementary students in Aceh-Indonesia. In addition, Jupri (2017) applied RME in geometry learning which involved pre-service elementary teachers. Besides, Nurhayati & Hartono (2017) also investigated the difference in concept understanding of junior high school students who were involved in STAD type cooperative learning combined with RME and the students who were enrolled in a regular class. The results of the previous studies explained earlier show that RME can be effectively used to predict students' cognitive achievement in mathematics. Other research separately analysed the use of snake and ladder in learning. Reid & Niekerk (2014) promoted snake and ladder in learning which involved generation Z learners. The results of the research suggested snake and ladder as a game that will appropriately support gen Z learning since it has been proved to have a long-term effect on students' awareness and behaviour. Rossiou & Papadakis (2007) have developed learning using snake and ladder to assist senior high school students to study logarithm. Findings of the research showed that the motivation of the students improved so that they also improved their effort in solving problems. In addition to that, misunderstanding and misconception related to learning materials can be fixed.

The research results have proved that RME and snake and ladder are able to encourage students to learn and as a result improve their cognitive achievement. It indicates that the information on how RME combined with snake and ladder specifically affect students' cognitive achievement is still limited.

The significance of this research is its emphasis on geometrical concept which is vital to building mathematics discipline. Regardless of the fact, geometrical concept is often misconceived. Therefore, the use of RME in the classroom can provide examples for students based on their daily activities which happen to assist them in solving their problems and misconceptions and as a result, improve their cognitive achievement. This research, thus, aimed to investigate the difference in cognitive achievement of students who learned with RME and of those who were engaged in conventional learning.

LITERATURE REVIEW

Realistic Mathematics Education (RME) Approach

Since 1970s, Utrecht University owned a research institution which always attempted to renew mathematics learning. The Freudenthal Institut was pioneered by Hans Freudenthal. It was based on the Netherlands and had been active from 1905 to 1990. Hans' work was called *Realistic Mathematics Education* (RME). RME was developed on daily life concepts. It was then used in many countries such as the United States and some African countries. Research conducted in some countries (including developing countries such as Indonesia) has proved that RME is a promising approach to fix and improve students' understanding of mathematics concepts (Armanto, 2002; Fauzan, 2002).

RME has a purpose to change mathematics learning into more fun and meaningful for students by introducing them into problems within contexts. RME starts with picking up problems relevant to students' experiences and knowledge. The teacher then acts as a facilitator to help students solve the contextual issues. This problem-solving activity which is contextual is believed to bring positive impacts to students' cognitive achievement especially related to their ability in understanding mathematics (Bonotto, 2008**).** The best way to teach mathematics is to provide students with meaningful experiences by solving issues that they face every day or in other words by dealing with contextual problems.

Mathematics learning would be more effective if students are able to work to process and change information actively. RME has emphasized the use of learning aids in learning which is related to students' ability. Realistic refers to asking students questions that they can think of (Wijdeveld, 1980). It was then followed by students solving mathematics problems (Treffers, 1987). Instructions in RME are mainly focused on students and the development of their ability in learning mathematics. Students' activities are mostly interactive and they are designed to build students' interest in studying mathematics (Fauzan, Slettenhaar & Plomp, 2002).

RME can increase students' logical, critical, and creative thinking (Ruseffendi, 1990; Usdiyana, Purniati, Yulianti, & Harningsih, 2013; Saefudin, 2012; Sembiring, Hadi, & Dolk, 2008). It helps construct learners' cognition at every stage of creative thinking. Based on some literature and research, creative thinking process is actually more oriented and concentrated on individuals' cognitive and intellectual functions, particularly in creative problem solving (Almeida, Prieto, Ferrando, Oliveira, & Ferrandiz, 2008; Isaksen & Treffinger, 2004). The structure of the intellectual ability is systematically perceived as a boost for students' creative thinking and achievement.

RME is oriented on empowering mathematization as a key process to mathematics learning. Mathematics is not only for mathematician, but it is involved in someone's daily life. Mathematization helps students connect ideas to rediscover, which means that it constitutes a process in which students formalize their informal understanding and intuition. Freudenthal uses the mathematization concept in developing RME. This process includes two aspects that are horizontal and vertical mathematization. Horizontal mathematization is related to transforming problems found every day to symbols meanwhile vertical mathematization is a process that occurs within the scope of the symbols (Heuvel & Panhuizen, 2003). RME draws these two approaches closer so that they can be related to each other and sustainable. In other words, learning starts from an informal step which later directs students to do mathematization of real world problems represented by symbols. After that, the students can continue with vertical mathematization by using models to draw more general conclusion.

RME Learning Characteristics

Since RME was introduced, it has established mathematics curriculum and pedagogy. Clements & Sarama (2013) state that main characteristics of RME include the application of meaningful contexts, the development of model which lets the transformation happen from contextual to formal mathematics, the recreation of mathematics concepts by the students, the interaction between students and teacher, and the perception of mathematics as an integrated subject. These characteristics lead to the progressive mathematical process which lets learners associate problems with contexts, identify relevant mathematical concepts, solve problems, and interpret the solution based on their contexts. Yuwono (2007) simplifies RME characteristics into understanding contextual problems, discussing the problems, and providing solutions to the problems.

Mathematics Games

Games are activities that stimulate learners' cognition. Snake and ladder game is one of the ways to teach various skills and problem solving concepts as well as moral reasoning, including issues related to mathematics. It is a classic game that is still popular among children and adults nowadays since it can trigger cognition. This game can also assist children in socializing with their friends because it is usually played by two people or more or even in groups. Based on the explanation on the approach, methods, steps, and techniques to play snake and ladder, it is obvious that this game is able to shape students' emotions to be more aware and responsible for their learning either individually or in groups.

METHOD

Type of Research

This research was an experimental research employing control group pre-test and post-test design. This design was applied to evaluate effects of a treatment on a particular behaviour or to test them. In this research, the observation was conducted twice, once before the experiment started and once after it ended. Observation that was conducted before the experiment (O_1) was called *pre-test,* and observation that was conducted after the experiment (O_2) was called *post-test*.

Variables, Population, and Sample

There were two variables of this research. The first variable was learning approach which included RME and conventional learning as the dependent variable. The second variable was students' cognitive achievement as the independent variable. The independent variable instrument was developed in the form of essay questions. The research was carried out in a public junior high school (SMP) in Ambon. Purposive sampling was used as the sampling technique. Students' daily test scores were used to determine the students' average score. Based on the scores, two classes which had relatively similar average score were chosen as participants. The two classes (out of 11) were selected as an experimental class and a control class. Each class consisted of 25 students; therefore, the total number of the participants was 50 students.

RME on Geometry

The performed characteristics of RME on geometry are understanding contextual problems, initiating group discussion, and solving the problems. The efforts to understand the contextual problems are shown in the beginning of the lesson where teacher asks students a few questions to direct them to learning. The students' understanding is then deepened through doing some activities related to learning materials provided in the students' worksheet (LKS). Next, the students discuss the problems in a group. Group discussion is a medium through which students can share their thoughts, ides, and opinions with one another as a form of responsibility for their tasks. During the process, students cannot work alone without teacher's assistance. Another RME characteristic is to solve the contextual problems through snake and ladder game. This research utilized snake and ladder as a medium to motivate students to solve contextual problems. The purpose is to help the students improve their understanding of the problems as well as to get engaged in the problem-solving process.

Followings are the instructions to use snake and ladder game in geometry learning:

1. Roll the dice. If you get 4, you have to move your token to the fourth square (to the right).
2. Keep doing the same thing. If your token stops at a rectangle or a square, then your group will have to answer a question provided inside the glass. The glass consists of questions related to rectangle and square (randomly selected).
3. Do solve the problems together with the members of your group.
4. Ask your teacher if you need assistance.

Questions provided for the game are those related to rectangle and square.

Rectangle problems

1. In front of Mr. Reno's house, there is a yard with an area of 840 m^2 and width 24 m. Find the length of Mr. Reno's rectangular yard.
2. Mr. Goris has a garden with an area of 12 hm^2 and one of the lengths is 6 hm. What is its width?
3. Lisa is going to make a tablecloth. Its length is 250 cm and its width is 150 cm. What is the area of the fabric Lisa needs in meter?

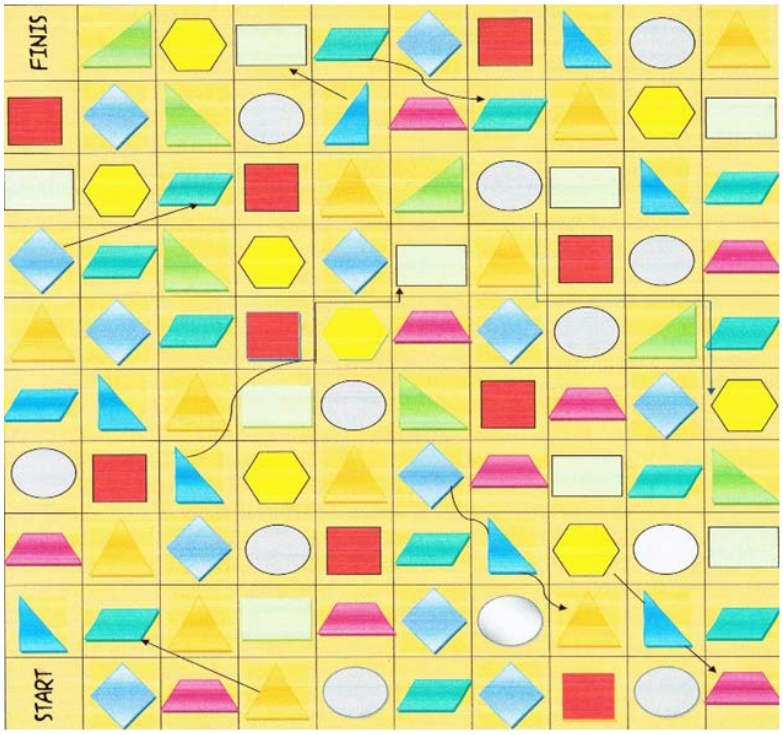


Figure 1. Mathematical Snake and Ladder on Geometry

4. The length of the backyard is 90 m and its width is 65 m. Fences are going to build around the backyard and they are worth Rp. 135.000.00, per meter. How much money is needed to install the fences?
5. Uncle Sam has an aquarium with an area of 300 dm^2. What is the length and the periphery of the aquarium?

Square problems

1. Find the area of a square garden if the side length is 25 m.
2. A garden has an area of 625 m^2, find the circumference of the garden.
3. A garden is a square. Determine the circumference.
4. The side length of a square floor is 6 meter. On that floor will be installed 30 x 30 cm^2 tiles. How many tiles are needed to cover the surface of the floor?
5. Mr. Joko is a contractor. He plans on buying a yard somewhere. The yard is worth Rp.350.000,-. per m^2. If the yard is a square with the size of 30 x 30 m, how much money should be provided by Mr. Joko?

RESULTS

The results of the observation indicated that the students still found some difficulties in solving the problems. The question was "a school yard is a square of which circumference is 168 meter. Find the area of the yard."

Figure 2 shows that the student did not solve the side length of the square (S). **Figure 3a** shows that the student multiplied the number given as the circumference. **Figure 3b** describes that the student summed the circumference as the area of the square.

Research findings describe students' cognitive achievement after hypothesis testing. Data was recorded in the form of pretest and post-test average scores as is presented by **Figure 2**.

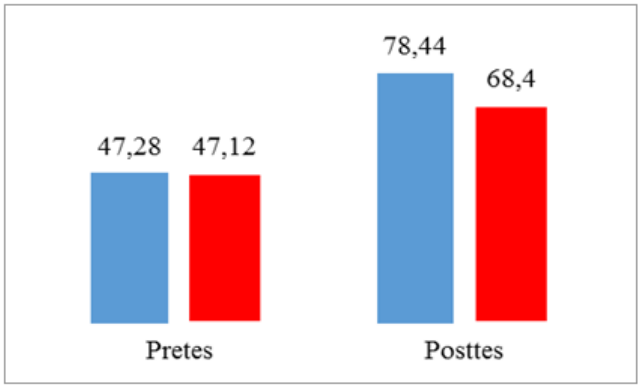
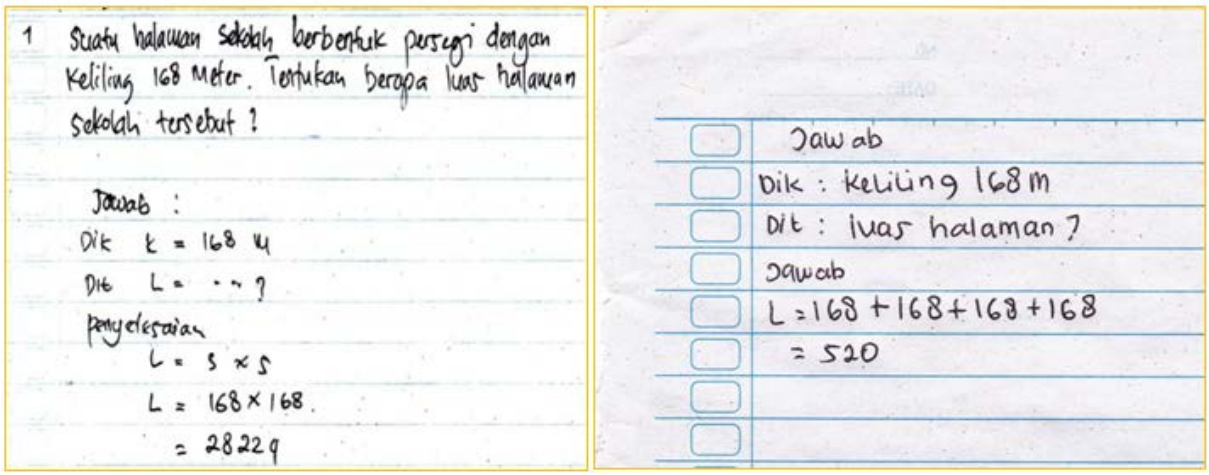


Figure 2. The Average Scores of Students' Pretest and Post-test
= scores from the experimental group of students
= scores from the control group of students



(a) **(b)**

Figure 3. Students' Worksheet **(a)** Students' Worksheet A **(b)** Students' Worksheet B

Table 1. Data on Students' Cognitive Achievement

Group	Pretest	Posttest
Experiment	47.28	78.44
Control	47.12	68.40

The description of the data is presented by **Table 1**.

Table 1 shows that the average score of students from the experimental group is higher than of students from the control group; it is 31,16 > 21,28. It indicates that there was a difference in cognitive achievement of the students who learned with RME and of the students who were engaged in conventional learning. Prior to the hypothesis testing, some tests were conducted using SPSS 20.0 Program. They are described as follows.

Normality Test

Normality test was executed using the Kolmogorov-Smirnov calculation on the experimental class and control class. The significance value (Z) *Asymp.Sig.2 tailed* of the experimental group was 0.200. Residue is normally distributed if the significance value is bigger than 0.05 (Leech, Barret, & Morgan, 2005). Since the significance value was bigger than the significance level of 5% (0.200>0.05), it can be concluded that the data was distributed normally. Meanwhile, the significance value (Z) *Asymp.Sig.2 tailed* of the control group was 0.140. Residue is normally distributed if the significance value is bigger than 0.05. Since the significance value was bigger than the significance level of 5% (0.140 >0.05), it can be concluded that the data was distributed normally.

Table 2. The Result of Homogeneity Test

Class	$F_{calculated}$	F_{table}	*Sig*	α	Conclusion
Experimental and control	2,014	4,46	0,162	0,05	H_0 is accepted

Table 3. The Result of Hypothesis Testing Using t-test

Class	$t_{calculated}$	t_{table}	*Sig*	α	Conclusion
Experimental and control	3,320	1,6772	0,002	0,05	H_0 is accepted

Homogeneity Test

To investigate the homogeneity of the students' ability in both classes, the two-variable homogeneity test was conducted using Levene's test to compare variance from both classes. The result of the test is depicted in **Table 2**.

Table 2 shows that $F_{calculated}$ = 2.014 is smaller than F_{table} = 4.25 and the *Sig. v*alue is bigger than α = 0.05 which is 0.162. It suggests that H_0 can be accepted so that it can be concluded that variance of both classes was homogeneous.

Hypothesis Testing

The result of the normality test using chi-square test showed that samples were normal. Also, the homogeneity test using Fishers test confirmed that both classes were homogenized. Therefore, hypothesis testing using t-test could be conducted. The result of the t-test is presented in **Table 3**.

Table 3 shows that $t_{calculated}$ = 3. 320 is bigger than t_{table} = 1.6772 and *Sig.*(*2-tailed*) value is smaller than α = 0.05 which is 0.002. It suggests that at the significance level of α = 5% (0.05), H_a was accepted and H_0 was rejected. This result indicates that there was a difference in achievement of students who learned with RME and of those who learned with conventional learning, particularly on geometry subject.

The difference was also shown by the average score of the experimental class (78.44) which was higher than of the control class (68.40). Besides, the research findings also suggested that RME increased students' interest in learning either individually or in groups to find a solution to mathematical problems. Despite the fact that there were some students still facing some difficulties in solving the problems, the results of the research showed that the teacher could handle it by offering solutions, guidance, and explanation to the problems.

The t-test was conducted to investigate the difference between the experimental class and the control class. The result of the t-test showed that $t_{calculated}$ = 3.320 was bigger than t_{table} = 1.6772 and *Sig.* (*2-tailed*) value was smaller than α. Then, it can be concluded that there was a difference in cognitive achievement of the students who learned with RME and of the students who were engaged in conventional learning, particularly in solving geometry problem.

DISCUSSION

The Results of Test Observation on Mathematical Ability

An observation was conducted before performing any intervention. The result of the observation showed that the students found some difficulties in solving mathematical problems. This occurred for some reasons related to the students themselves and to the teacher. It was obvious that the students did not understand the material thoroughly or only understood it partially. This partial understanding made the students unable to apply mathematics in their daily lives. As a result, it was difficult for them to connect the concept that they already knew with the concept they were learning and it slowed them down. Besides, the knowledge was only stored in their short-term memory because there was no lesson review after school. Learning should be continuous so that knowledge can be stored in the long-term memory. If it is not, only little information will remain when a new one is absorbed.

Another factor that affected the students' ability in solving problems was the teacher who applied less effective approach or learning strategies. Mathematics learning mostly contained transfer processes and also explanations of formulas and calculation procedures that are considered troublesome for the students. Such processes only activated the students' left brain so that their brain was overloaded with many formulas, symbols, logics, and calculation steps. The mathematics teacher had not yet found more fun and more appropriate techniques or strategies that can be applied to learning. Lecture, asking questions, giving assignment only burden students since they have to store a lot of information which can make them feel suffocated. This condition was worsened by the fact that the teacher did not connect mathematical concepts to the students' daily lives. Therefore, a mathematics

teacher needs to be aware of the condition and as a result change his/her paradigm and learning patterns. As an initial step and also self-evaluation, the teacher can contemplate some reflection questions as follows: "Has learning been meaningful?", "Have students understood the materials thoroughly?", "Do the students know why or do they only know how?"

Comparing Students' Achievement (RME and Conventional Learning)

The research findings showed that there was a significant difference between both treatments. It resulted from different learning steps and materials delivery. RME gave the students more opportunity to actively participate in learning through understanding contextual problems, discussing the problems, and finding the answers. They were given freedom to think and discuss with their partners. They were welcome to share their ideas and opinions with their peers especially in discovering mathematics concepts and build their knowledge. They were also able to draw a conclusion from what they had learned. That way, their cognitive achievement improved compared to the students who learned with conventional learning.

RME is an approach which allows teacher to bring contextual problems into the classroom as an initial step of learning. RME trains students to discover concepts. Besides, it also encourages students to be actively engaged in learning activities. Students are required to have an initiative to solve contextual problems given by the teacher with their own way. Furthermore, RME allows students to learn individually or in groups. Students' activities include actively following teacher whom they can work together with in solving realistic contextual problems. RME is a way out to change students' perception on working in a group, associating what they learn and what they know, and constructing knowledge.

According to Freudental, mathematics should not be learned as a product, but as an activity through which learners can actively construct their own mathematical concepts (Wijaya, 2012). In addition to that, Pitajeng (2006) states that mathematics learning needs to involve learning aids such as real or concrete things modified for children in order that the concepts can be easily understood. These aids will engage students into learning or discussion. Such learning process is realized in one of RME characteristics that is the use of contextual problems. This RME feature differs it from conventional learning which does not involve students as learning subjects. In conventional learning, students only follow concepts and examples the teacher gives. They tend to memorize rather than to understand. Therefore, the focus of learning is merely students' calculation skill.

The snake and ladder game in this research can help remind students to apply geometry concepts in their daily lives. This game, which was specially designed for group work, can also encourage students to review the lesson so that they can strengthen their memory and improve their understanding of the materials. Hodkiewicz (2015) emphasizes that games including snake and ladder can stimulate students' interest in solving problems in groups and students' acceptance to new ideas. Moreover, snake and ladder can also develop students' emotions and self-confidence which results in students' active participation in finding solutions to problems.

The fact that RME can improve students' cognitive achievement was also confirmed by Wirama (2014) who proved that students who learned with RME achieved better than students who learned with conventional learning. The average score of the students who learned with RME was 75.8, meanwhile the average score of the students who learned with conventional learning was 62.21. In similar fashion, Barnes (2004) affirmed that RME was effective to help students class 8B to learn topics of place value in whole numbers and decimals, and fractions. Findings by Jupri (2017) also approved that the RME principles could be beneficial in analyzing geometrical problems which reflect students' reasoning and problem solving skill. The students were active in the problem-solving process due to their increased interest in learning. In this context, RME helped grow students' initiative to evaluate real life issues and trigger their reasoning skill. In regards with that, the results of students' interview and test showed that RME had a potential to engage students in mathematics learning and improve their confidence (Bray & Tangney, 2015). These research results have shown that RME is effective in improving students' motivation, self-confidence, problem-solving ability, and reasoning which results in an increase in their cognitive achievement.

CONCLUSION

Findings and results of this research have provided information that there was a difference in cognitive achievement of students who learned with RME and of students who learned with conventional learning. Mathematics teachers need to apply RME in the classroom to make abstract mathematical concepts more understandable. RME also helps teachers to simplify and realize mathematical concepts. Therefore, the teachers need to be more creative and innovative in designing learning with this approach. It is necessary for the teachers to develop more appropriate learning media, strategies, or model which are more suitable with learning materials or with the contexts that their students are dealing with. Besides, it is recommended for schools to create more contextual environment which is rich of information about how to solve real life problems. It is also advisable that future research can further explore how RME contributes to students' cognitive achievement in mathematics at

different levels of education. Those research can also investigate the effect of RME on students' attitude, problem-solving ability, learning interest, or other variables related to mathematics learning.

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