Mathematical Connection Middle-School Students 8th in Realistic Mathematics Education

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Abstract. This study was conducted to notice the effect realistic mathematics education in improving 8th grade Middle-School students’ mathematical connection by employing measuring tools of a mathematical connection test and observation sheet, which were developed, was distributed to 37 experimental group students and 37 control group students, which makes 74 learners in total. This study was accompanied experimental by pre-test – post-test control group design. This participant was studying at 8.5th grade as the experimental group and 8.6th grade as the control group from a Middle-School 2 Candi Sidoarjo. Realistic Mathematics Education was implemented in the experimental group while the Control group was implemented to the current Curriculum. As a result of the conducted experimental group, it was being discovered that mathematical connection tests and observation sheets of experimental group students are better than control group students. It was be discovered too, based on the results of the mathematical connection test, 83.78% of students obtained N-Gain more than or equal to 0.7. Therefore, it is possible to say that realistic mathematics education is more efficient than learning in the control group.

1. Introduction
Mathematical connections are one of the abilities that must be possessed to solve problems. This is supported by the statement NCTM, "Mathematics is not a collection of separate strands or standards, even though it is partitioned and presented in this manner" [1]. The ability to recognize, use, understand the interrelationship between mathematical ideas, and form a connection between one idea to another to obtain an overall connection, and to recognize and apply mathematics to situations outside mathematics is called the ability mathematical connection. The ability of mathematical connection as an aspect of mathematical skills that students need to develop. This is contained in the 2013 curriculum mathematics learning objectives, "The purpose of learning mathematics due to students understand mathematical concepts, explaining the interrelationships between concepts and applying concepts or algorithms flexibly, accurately, efficiently, and precisely in problem-solving" [2].

The ability of mathematical connections is very important to be developed in the process of learning mathematics. This is supported by the statement NCTM "To help students build a disposition to use a connection in solving mathematical problems, rather than see mathematics as a set of disconnected, isolated concepts and skills" [1]. The ability of mathematical connections is needed by students, especially in solving problems that require a relationship between mathematical concepts to other concepts in mathematics and other scientific disciplines or in real life [3]. The student’s ability in mathematical connections in various schools in Indonesia is still relatively low and moderate. This is based on several research results that say that students’ mathematical connection skills are low and students still have difficulty in connecting mathematical concepts [4, 5, 6, 7]. This is also supported by
the results of the PISA survey which shows that mathematics achievement in Indonesia at the Middle-School level is always fixed on low numbers and Indonesia is ranked 64th out of 72 countries with a score of 386 [8].

TIMSS research results on students in Indonesia, especially mathematics, are ranked 45th out of 50 countries [9]. Data showed that students were still weak in all aspects of content and cognitive, one of which has not been able to associate three-dimensional concepts and two-dimensional concepts that result in low mathematical connection skills of students. From this problem, a low mathematical connection indicates that students cannot make their mathematical connections. This is consistent with the opinion of Sawyer who said that: "Making connections is the basis for mathematics education which is influenced by their teaching practices in several important ways. Who demonstrates the ability to make connections between mathematical knowledge and other forms of disciplinary knowledge, and between mathematical and real-life knowledge” [10].

Based on the above description of the learning approach that can be applied to improve students' mathematical connection skills namely Realistic Mathematics Education (RME). Realistic Mathematics Education is appropriate for students because it uses contextual problems as the starting point of learning. According to Freudenthal mathematics should not be conveyed to students as a tool (tool) that is ready to be used, but a form of activity constructing mathematical concepts [11]. Under this statement, mathematics learning in the classroom emphasizes a link between mathematical concepts of the student experience in their daily lives and it is very necessary to re-apply the knowledge of students to mathematical concepts in real life. The approach to learning mathematics that directs the mathematical knowledge of everyday students and applies mathematics to their daily lives is Realistic Mathematics Education. So, it can be said that mathematics learning trains students 'logical reasoning by increasing students' ability to mathematical connections. Therefore, the Realistic Mathematics Education approach is appropriate for improving students' mathematical connection skills.

1.1 Realistic Mathematics Education

Realistic Mathematics Education (RME) is a mathematical teaching theory, developed by the Freudenthal Institute in the Netherlands as a reform movement that challenged traditional mathematics education with a mechanistic approach, this approach is based on Freudenthal's assumption "mathematics is a human activity” [12, 13, 14, 15, 16]. This approach characterizes the mathematical activity as an activity of solving problems, finding problems and organizing the subject matter. The main activity is organizing or mathematical. This approach emphasizes student activity and not as passivity. The mathematical activity in question is the activity of rediscovering mathematical ideas and concepts by exploring the real world under the guidance of the teacher as a facilitator. The basic principle of RME refers to guided discovery, didactic phenomenology, and mediating the principle of the model. All these characteristics are inspired by Freudenthal, the basic principle of this RME is 'mathematics as a human activity' [15, 17, 18, 20]. This idea places a heavy emphasis on students who build their knowledge with the guidance of teachers in the learning process of mathematics in the classroom.

Two types of mathematical formulations by Treffers, namely horizontal and vertical mathematics. Examples of horizontal mathematicians are identifying, formulating, and visualizing problems in different ways, and transforming real-world problems into mathematical problems. Examples of vertical mathematics are a representation of relationships in formulas, enhancement, and adjustment of mathematical models, the use of different models, and generalizations. Both types of mathematicians get balanced attention because these two mathematicians have the same value [16]. The real world here is used as a starting point for learning mathematics, such as other subjects, the environment, and everyday life. This approach emphasizes processes more important than results. PMR uses mathematical terms which are interpreted as "Mathematically" consists of two processes namely horizontal mathematical and vertical mathematical. Both processes are interpreted as a guided reinventing activity [19]. In line with Freudenthal, "horizontal mathematical means moving from the real world into the world of symbols to produce mathematical concepts, principles, or models of everyday contextual
problems, while vertical mathematical means moving in the world of symbols themselves to produce concepts, principles, or mathematical models of mathematics " [15].

The following are realistic mathematics education principles which are guided reinvention and progressive mathematization, didactic phenomenology, and self-developed models [20]. The following are the characteristics of realistic mathematics education approaches that are using context, using models, using student contributions, interactivity, and interrelationships between topics [16, 20, 21]. Based on the literature review, we make PMR-based mathematics learning steps that are under the principles and characteristics of RME, namely, first step: Understand contextual problems, second Step: Resolve contextual problems, third step: Compare and discuss, fourth Step: Conclude.

1.2 Mathematical Connections

One of the abilities that must be mastered by students in mathematics is mathematical connection skills, as recommended by NCTM, the Standard Process of Problem Solving, Reasoning and Evidence, Communication, Connection, and Representation, highlighting how to acquire and use content knowledge [1]. By statement NCTM," mathematical connections are the relationship between mathematical topics, the relationship between mathematics and other disciplines, and the relevance of mathematics to the real world or in everyday life" [22]. Mathematical connections are connections of mathematics to mathematics itself, mathematical connections to other subjects, mathematical connections to their applications, and mathematical connections to real problems around students through mathematical modeling [23]. In connection with understanding this mathematical connection, we need to note that in mathematics between one concept and the other there is a close relationship, not only in terms of sides but also in terms of the formulas used. One material may be a prerequisite for another material, or a certain concept is needed to explain another concept. This is by Bruner's association proposition which states that in mathematics each concept is related to one another [24]. Mathematical connections are the ability of students to (1) recognize the same representation with the same topic, (2) associate procedures in one representation with procedures in the same representation, and (3) use and value relationships between mathematics and other scientific disciplines" [25]. When students and teachers continue to" think connections "mathematics will grow and become dominant" [26]. In general, suggests that mathematical connection capabilities include “Link conceptual and procedural knowledge, Use mathematics in other curriculum fields, Use math in daily life activities, Look at mathematics as an integrated whole, Applying mathematical thinking and modeling to solve problems that arise in other disciplines, such as art, music, psychology, science, and business, Use and value connections between mathematical topics, Recognise equal representation from the same concept [26].

The purpose of this study was to notice the effect of realistic mathematics education in improving 8th-grade Middle-School students’ mathematical connection.

2. Methods

This study used experimental research with the design of the two-groups of pretest-posttest design. The study population was all 8th-grade students of Middle School 2 Candi Sidoarjo. The Sample of this study consists of 8.5th grade and 8.6th grade from the population sampling 8th grade with a total of 74 students. The experimental grade taught with problem-based learning is 8.5th grade which consists of 20 female students and 17 male students, while the control grade taught with conventional learning is 8.6th grade consists of 24 female students and 13 male students. Data collection tools developed in this study uses a mathematical connection ability test sheet (TKMM) and an observation sheet. The TKMM test instrument consisted of 4 questions on the topic of a prism. The observation sheet consists of observing teacher activities and student activities to see student activities during the lesson. Before conducting the research, the TKMM test instrument and observation sheet were validated by experts consisting of 3 lecturers and 1 mathematics teacher. After being declared valid with a validity coefficient of 0.81 and a reliability coefficient of 0.78.
Furthermore, the TKMM description test items were tested to students to get the level of validity and the level of reliability of the instruments to be used, the TKMM items were tested outside the research subject. To measure the validity of an item, you can use the product-moment correlation formula below [27].

\[
r_{xy} = \frac{n\sum_{i=1}^{n} x_i y_i - (\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{\sqrt{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2} \sqrt{n\sum_{i=1}^{n} y_i^2 - (\sum_{i=1}^{n} y_i)^2}}.
\]

Then, to calculate the reliability coefficient the Alpha-Cronbach test item is used as follows [28].

\[
r_{11} = \left( \frac{n}{n-1} \right) \left( 1 - \frac{\sum_{i=1}^{n} \sigma_i^2}{\sigma^2} \right)
\]

Furthermore, to determining the level of improvement in the pretest (TKMM) and posttest (TKMM) results, the calculation results with formula below are further categorized and matched with an interpretation based on the criteria in Table 1 as follows [29].

\[
<g> \equiv \frac{\%<S_f> - \%<S_i>}{(100 - \%<S_i>)}
\]

where \(<S_f>\) and \(<S_i>\) are the final (post) and initial (pre) class averages on the "mathematical connection ability test, "a well-known test of mathematical connection ability".

### Table 1. N-Gain Value Criteria

| N-Gain  | Criteria      |
|---------|---------------|
| (<g>) ≥ 0.70 | “High-g”     |
| 0.30 ≤ (<g>) < 0.70 | “Medium-g”   |
| (<g>) ≤ 0.30 | “Low-g”       |

### 3. Results

Data Analysis pre-test results of TKMM were compared with the non-parametric Mann-Whitney U test. As a result of the comparison, there was no significant difference between the scores of experimental and control groups in terms of TKMM pre-test scores. Since TKMM post-test scores of experimental and control groups provide parametric testing propositions, they were compared with independent t-test.

### Table 2. Mann-Whitney U test results of TKMM pre-test scores

| Test | Group          | N  | Average | Total  | U   | P     |
|------|----------------|----|---------|--------|-----|-------|
| TKMM | Experimental   | 37 | 55.53   | 2776.5 | 472.05 | 0.205 |
|      | Control        | 37 | 51.21   | 2304.45 |       |       |

Hypothesis criteria: hypothesis (H₀) accepted if: \(T_{\text{count}} > T_{\text{table}}\) and hypothesis (H₁) rejected. The research hypothesis is as follows:

- H₀: There are no significant differences between students' pre-test and post-test scores which indicating an effect of teaching on students' mathematical connection.
- H₁: There are significant differences between students' pre-test and post-test scores which indicating an effect of teaching on students' mathematical connection.

### 3.1 Results of TKKM

The process of conducting study begins by giving TKMM tests to both classes to see the level of students' initial mathematical connection ability. After applying problem-based learning, a test is given to see the improvement of students' mathematical connection ability. The control grade and the experimental grade are given different learning treatments. Table 3 shows results TKMM to reveal if
designed instruction created a significant difference in students’ mathematical connection in terms of pre-test and post-test scores.

Table 3. Results of TKMM scores

| Test  | Class       | Number of Subject | Highest Score | Lowest Score |
|-------|-------------|-------------------|---------------|--------------|
| Pre-Test | Experiment  | 37                | 70            | 40           |
|         | Control     | 37                | 65            | 35           |
| Post-Test | Experiment  | 37                | 100           | 75           |
|         | Control     | 37                | 70            | 50           |

Based on Table 3 above, it was found that the students’ mathematical connection using realistic mathematics education showed better results by looking at the average obtained by students in the experimental grade and the control grade.

Then, the initial analysis is carried out normality and homogeneity test with the purpose to find out data from two groups with normal distribution and homogeneous data obtained. Next, the hypothesis test is performed to show the T \(_{value}\) calculated from the pre-test and post-test data. Based on statistical results, \(T_{count} = 17.656\) and \(T_{table} (N-2) = 1.689\). So that \(T_{count} > T_{table}\) is obtained, based on this hypothesis (H1) accepted and (H0) rejected, so it can be concluded that the students’ mathematical connection using Realistic mathematics education in experiments grade increases and is better than students who get treatment with conventional learning in the control grade. As well as seen from the posttest value of students that fulfills the number that gets a value above the Classical Completion Criteria. Learning completeness achieved by students in classical is more than 75%.

The average N-Gain value obtained by students in the experimental grade is 83.78% more than or equal to 0.7. It can be said that, while in the control grade that is 65% more than or equal to 0.3.

| N-Gain      | Criteria  |  |
|-------------|-----------|  |
| \((<g>) \geq 0.70\) | 83.78%    |  |
| \(0.30 \leq (<g>) < 0.70\) | 16.22%    |  |

3.2 Results of Observations

Based on observations during learning on experiment grade, the results indicate that the teacher’s activities in learning meet good criteria at each stage in the Realistic mathematics education. Then, student activities that meet active criteria in learning are marked by the ideal time set in the lesson plan to meet the time limit for effectiveness of tolerance and provide a positive response to mathematics learning in class. In mathematics learning takes place, students’ responses are positive about mathematical connection skills, because students are given contextual problems to connect the relationship between mathematics and mathematics itself, mathematics with other subjects and mathematics is associated with everyday life.

Based on observations made by observers, the following is a description of the learning process obtained. The stage of treatment or implementation of learning is carried out with several meetings. Each meeting lasts 90 minutes with an estimated learning time from the initial activity to closing. The material discussed in each meeting in this study was prism material. For each meeting, students are given contextual problems related to the prism material, in this case, the surface area and volume of prisms that will be discussed with student group friends. In the initial activity of learning, the teacher arranges classes for learning activities and conveys the purpose of the material to be studied. Next, the teacher forms a group based on gender and the level of ability of students with the aim that students will hold group discussions and solve problems that have been delivered by the teacher. At first, students still have difficulty finding mathematical ideas on the problems presented, but at the next meeting students have begun to recognize mathematical ideas and have been able to represent them in symbolic
form, then students make models or procedures, so students can find and draw conclusions from the material that has been taught.

When the material discussion takes place, several students in each group ask the teacher questions about the contextual issues they discussed. In the learning process, the teacher does not directly answer questions from students, but the teacher simply repeats the material and provides reasonable guidance, so students can find their answers. After the group discussion is complete, the teacher asks one of the representatives from each group to present the results of their discussion and write them on the board. After the group presents and presents the results of the discussion, the teacher checks whether the results are by what is expected in the learning objectives. Then the teacher will explain further to confirm the results of the discussion from each group. At the end of the lesson, the teacher and students summarize or conclude the material that has been taught with the guidance of the teacher.

4. Discussion

In general, the results of this study can improve students' mathematical connection skills. This study shows that the average mathematical connection ability of students who use the Realistic Mathematics Education (RME) increases and is better than the class with conventional learning. By using the Realistic Mathematics Education (RME) which is connected with the mathematical concepts themselves, other scientific concepts and other daily life, thus learning will be more meaningful and students' mathematical connection abilities increase and become better.

Learning theory is a guideline for teachers to help students develop their cognitive, social, and spiritual. The development so far with Realistic learning Mathematics Education (RME) has always been based on 4 theories namely Piaget's theory, Vygotsky's theory, Bruner's theory and Ausubel's theory [30]. By the theory of learning, learning and thinking change and develops cognitive structures. In his theory, Piaget suggested that a person's cognitive structure occurs because of the process of adaptation. Adaptation is the process of adjusting schemes in responding to the environment through two processes of assimilation and accommodation. In fact, according to Slavin, “assimilation is an interpretation of new experiences to existing schemes” [30].

The learning process with RME is very closely related to theory, it is based on Piaget's theory, because realistic mathematics learning focuses on how students think, not focusing on the results of student completion. Furthermore, students who are given contextual problems will be allowed to find their ideas to solve problems and represent mathematical symbols. One important theory in the developmental psychology of students is Vygotsky's theory [30]. This theory is following the Realistic Mathematics Education Approach (RME), which is a contextual problem that is presented to students in understanding and completing it designed in the form of groups, and in this group, there are interactions between students and students and teachers in understanding and resolving the contextual problems presented earlier. This approach each student will feel confident and responsible for their knowledge obtained from the results of the discussion.

Learning mathematics is learning about the concepts and structures of mathematics found in the material studied and for discovering the relationship between the concepts and mathematical structures of Bruner [31]. Through these concepts and structures, so that material will be comprehensively understood. Besides, student knowledge is easier to remember and last longer if the material being studied has a structured pattern. So, it can be concluded that Bruner's theory is following RME, the suitability of first guided rediscovery and progressive mathematics, and conformity with the second principle, didactic phenomenology, conformity with the characteristics of the first RME is to use context, third is student contributions and fourth is interactivity.

Learning must be meaningful when the information learned by students is governed by cognitive students [31]. Ausubels’ theory, students can associate their new knowledge with cognitive. This way students will have strong and easy memories in transferring their knowledge. If students try to link new information into their knowledge then learning will be meaningful to them. Based on some of the descriptions above, this shows that RME is appropriate and relevant to Ausubels’ theory because RME emphasizes understanding more than just memorizing. Besides, the relationship between information to
be learned on the cognitive structure of students in the RME approach arises when contextual problems are given that are close to the actual student environment or students can imagine so that they can help students learn meaningfully.

5. Conclusion
Based on the analysis of the results of the above data obtained from the pre-test, post-test, and observation in the experimental class and the control class. The conclusions in this study conducted at Middle-School 2 Candi Sidoarjo are presented below:

- The ability of students' mathematical connection to use realistic mathematics education in the experimental grade increased significantly and was better than the control grade.
- The observations, the activities of the teacher are done well and the students' activities show that they are actively characterized by students who are more enthusiastic in learning mathematics using realistic mathematics education.
- Based on the results of students' mathematical connection tests, 83.78% of students obtained an N-gain more than or equal to 0.7. Therefore, it is possible to say that realistic mathematics education is more efficient than learning in the control grade.

The conclusion obtained above is that learning mathematics using realistic mathematics education can improve mathematical connection students and teachers must master learning models such as realistic mathematics education so that the learning process in the classroom becomes more active, diverse, and learning will be meaningful so that students' knowledge will last a long time and will improve student learning outcomes (Mathematical connection) for the better.

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