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Improving the Mathematical Connection Ability of Middle-School Students through Realistic Mathematics Approach

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Abstract

This present study describes how do the process and results of the development of mathematics teaching based on realistic mathematics education to enhance the mathematical connection ability of Middle-School students. The teaching material development model refers to the 4-D Thiagarajan model which has 4 steps namely defining, designing, developing, and disseminating. This participant is studying distributed to learners from a Middle-School 2 Candi Sidoarjo. The study data were obtained with a validation sheet, an observation sheet of teacher and student activities, a student response questionnaire, and a mathematical connection ability test. The products of this study are the learning plan, student worksheets, and mathematical connection ability tests. The results showed that the learning material fulfilled the validity, practical and effective. The results of students' mathematical connection ability tests improved based on t-tests correlated and N-gain analysis. Therefore, it is possible to say that the development of mathematics teaching based on realistic mathematics education can enhance the ability of mathematical connections. As a suggestion, teachers in managing mathematics teaching are very necessary to develop the right tools, so that it has a positive impact on student learning outcomes, especially the ability of students' mathematical connections.

Keywords: Realistic Mathematics Education, Mathematical Connection, Middle-School, 4-D Model

Abstrak

Penelitian ini menjelaskan bagaimana proses dan hasil pengembangan pengajaran matematika berbasis pendidikan matematika realistik untuk meningkatkan kemampuan koneksi matematis siswa SMP. Model pengembangan bahan ajar mengacu pada model 4D Thiagarajan yang memiliki 4 langkah yaitu mendefinisikan, mendesain, mengembangkan, dan menyebarluaskan. Subjek penelitian adalah siswa kelas VIII SMPN 2 Candi Sidoarjo. Data penelitian diperoleh dengan lembar validasi, lembar observasi aktivitas guru dan siswa, angket respons siswa, dan tes kemampuan koneksi matematika. Produk dari penelitian ini adalah rencana pembelajaran, lembar kerja siswa, dan tes kemampuan koneksi matematika. Hasil penelitian menunjukkan bahwa materi pembelajaran memenuhi syarat validitas, praktis, dan efektif. Hasil penelitian menunjukkan bahwa materi pembelajaran memenuhi validitas, praktis dan efektif. Hasil tes kemampuan koneksi matematika siswa meningkat berdasarkan t-tes berkorelasi dan analisis N-gain. Oleh karena itu, dimungkinkan untuk mengatakan bahwa pengembangan pengajaran matematika berdasarkan pendidikan matematika yang realistis dapat meningkatkan kemampuan koneksi matematika. Sebagai saran, guru dalam mengelola pengajaran matematika sangat diperlukan untuk mengembangkan alat yang tepat, sehingga memiliki dampak positif pada hasil belajar siswa, terutama kemampuan koneksi matematika siswa.

Kata kunci: Pendidikan Matematika Realistik, Koneksi Matematika, Sekolah Menengah Pertama. Model 4-D

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Introduction

Mathematics subjects consist of interrelated concepts. This is not only between concepts in mathematics, but mathematics is also related to other disciplines, and mathematics is related to real life.

This is supported by the statement of NCTM, " Mathematics is not a collection of separate strands or standards, even though it is often partitioned and presented in this manner. Rather, mathematics is an integrated field of study. When students connect mathematical ideas, their understanding is deeper and more lasting, and they come to view mathematics as a coherent whole" (NCTM, 2000). Inline also expressed by Kline (2015) that "Mathematics is not an autonomous knowledge that can be perfect by itself, but was mainly to help people in understanding and mastering the problems of social, economic, and nature".

Therefore, the ability of mathematical connections is very important to be developed in the process of learning mathematics. This is supported by the statement of NCTM "To help students build a disposition to use connections in solving mathematical problems, rather than seeing mathematics as a set of disconnected, isolated concepts and skills" (NCTM, 2000). This is supported 2013 curriculum mathematics learning goals, "The purpose of mathematics learning is for students to understand mathematical concepts, explain the interrelationships between concepts and apply concepts or algorithms flexibly, accurately, efficiently, and precisely in problem-solving" (Depdikbud, 2014). Similarly, based on the results of research which states that "The ability of mathematical connections will be greatly needed by students, especially to solve problems that require a relationship between mathematical concepts with other concepts in mathematics and other disciplines or in everyday life" (Rohendi & Dulpaja, 2013). Mathematical connection skills are important but students who master mathematical concepts do not necessarily have good mathematical connections. In one study it was found that students were often able to register mathematical concepts related to real problems, but only a few students were able to explain why the concepts were used in the application (Bergeson, 2000). Therefore, the ability of mathematical connections as an aspect of mathematical skills that need to be developed by students.

The ability of students' mathematical connections in various schools in Indonesia is still relatively low and moderate. This is based on several research results which say that students' mathematical connection ability is low and students still experience difficulties in connecting mathematical concepts (Hendriana *et al*, 2014; Suminanto & Kartono, 2015; Warih, 2016; Latif, 2017; Siregar & Surya, 2017; Haji *et al*, 2017; Nugraha, 2018). This is also supported by the results of the PISA survey which shows that mathematics achievement in Indonesia at the middle-school/high-school level is always fixed at low numbers and Indonesia is ranked 64th out of 72 countries with a score of 386 (OECD, 2018). From the problem of the low mathematical connections above it can be seen that students cannot make mathematical connections by themselves. This is supported by the opinion said that "Making connections was fundamental to mathematics education influenced their teaching practice in several important ways. The effectiveness of their practice was evidenced by the examples of students in classes taught by these teachers who demonstrated the ability to make connections between mathematical knowledge and other forms of disciplinary knowledge and between mathematical knowledge and real-life " (Sawyer, 2008). Other factors that cause the low ability to connect are also stated by "One of the reasons for the low ability of students' mathematical connections lies in the modeling factors of learning or the use of teaching methods" (Ary *et al*, 2018).

The main purpose of mathematical connections is emphasized on students who play a major role in making connections. For the learning objectives to reach the expected targets, it is necessary to choose an appropriate learning approach, and also need to develop learning tools following the learning approach used. The learning approach must be able to make students active in learning activities, make learning meaningful, and be able to improve students' mathematical connection skills. This is supported by Haggarty and Keynes's statement that " to improve mathematics teaching and learning in the classroom, efforts are needed to improve the understanding of teachers, students, materials used for learning and interactions between them. For learning objectives to achieve goals well, besides the need for selecting appropriate learning methods and strategies, it also requires the development of learning tools that are appropriate to the learning methods and strategies used "(Hasan, 2006).

Based on the previous descriptions it can be concluded that the problems faced by researchers are caused by a lack of information or guidance using learning tools that can later activate students in learning activities so that learning activities are student-centered. Therefore, we need learning tools that can enable students to learn, connect learning material with students' daily lives, connect learning that students have previously learned with current learning. One alternative learning that can activate students, help students associate the concepts to be learned with those that have been learned and get along with everyday life is a realistic approach.

A realistic approach is one solution to overcome these problems because Realistic Mathematics Education uses contextual problems as a starting point for learning. According to the principle of realistic approach is the involvement of students in mathematics must begin in a meaningful context. The development of that understanding and the ability to create a sense of mathematical representation begins with the students' formal reasoning (Web *et al*, 2011). RME theory focuses on reinvention itself through mathematical processes and takes into account informal strategies and interpretations, through contextual problems based on real experiences (Kwon, 2002). A realistic based learning approach can also improve students' mathematical connection skills. As a result, it shows that the ability of students' mathematical connections increases by using realistic approach based learning. Students are more enthusiastic about using a learning approach based on a realistic approach (Menanti *et al*, 2018).

Realistic Mathematics Education

Realistic Mathematics Education (RME) is a domain-specific theory of instruction for mathematics education (De Lange, 1987; Streefland, 1991; Gravemeijer, 1994; De Lange, 1996; Van den Heuvel-Panhuizen, 1996; Freudenthal, 2006; Treffers, 2012). This theory is the Dutch answer to the need, felt throughout the world, to reform the teaching of mathematics. Based on Freudenthal's idea that mathematics to be of human value must be connected with reality, remain close to children and must be relevant to society, the use of realistic contexts is one of the defining characteristics of this approach to mathematics education (Freudenthal, 2012). In RME, students must learn mathematics by developing and applying mathematical concepts and tools in situations of everyday life problems that make sense to them.

On the one hand, the 'realistic' adjective certainly corresponds to how mathematics teaching and learning look in RME, but on the other hand, this term is also confusing. In Dutch, the verb 'zich realiseren' means 'to imagine'. In other words, the term 'realistic' refers more to the intention that students must be offered problem situations that they can imagine than to refer to 'reality' or the authenticity of the problem (Freudenthal, 2006; Van den Heuvel-Panhuizen, 1996). However, the latter does not mean that connections to real life are not important. This only implies that the context is not always limited to real-world situations. The fairy-tale fantasy world and even the formal world of mathematics can be very suitable contexts for problems, provided they are 'real' in the minds of students.

Three guiding heuristics for RME instructional design should be considered (Gravemeijer, Cobb, Bowers, & Whitenack, 2012). The first of these heuristics is reinvention through progressive mathematization. According to the reinvention principle, the students should be allowed to experience a process similar to the process by which mathematics was invented. The reinvention principle suggests that instructional activities should provide students with experientially realistic situations, and by facilitating informal solution strategies, students should have an opportunity to invent more formal mathematical practices (Freudenthal, 2012). Thus, the developer can look at the history of mathematics as a source of inspiration and at informal solution strategies of students who are solving experientially real problems for which they do not know the standard solution procedures yet (Streefland, 1991 & Gravemeijer, 1994) as starting points. Then the developer formulates a tentative learning sequence by a process of progressive mathematization.

Mathematical Connection

Mathematical connection ability is an ability that must be possessed by students in the field of mathematics. Thinking mathematically involves looking for connections, and making connections builds mathematical understanding, without connections, students must learn and remember too many isolated concepts and skills, and with connections, they can build new understandings on previous knowledge (NCTM, 2000). It is not only mathematical connections that are important but the awareness of the need for connections in learning mathematics is also important. If examined there are no topics in mathematics that stand alone without any connection with other topics. Connections between topics in mathematics can be understood by children if children experience learning that practice their connection skills, one of which is through meaningful learning (Bell, 1978). Connections between processes and concepts in mathematics are abstract objects meaning that these connections occur in students' minds, for example, students use their minds when connecting between symbols and their representations (Hodgson, 1995).

Many students see mathematics as a static science because they feel the mathematics they learn is not related to their lives. Very few students consider mathematics as a dynamic science, especially because more than 99% of the mathematics they learn was discovered by experts before the eighteenth century (Johnson & Litynsky, 1995). As students and teachers continue to "think connection" the connectedness of the mathematics will be grown and become dominant. When that occurs, al will wonder why anyone had ever thought of mathematics in any other way (Coxford, 1995). According to Sawyer (2008), "Students must become competent in perceiving the connections between mathematics and other forms of knowledge and between mathematics and their lived experience, as well as competent in applying the mathematical knowledge necessary to maximize the productivity of such connections ". The beauty of mathematics lies in the connection in mathematics itself. For mathematicians, this relationship is not only the beauty of mathematics but also brings up new techniques in solving problems. If students can make these connections, they too will feel the beauty of mathematics (Cuoco, 1995). Based on some of the statements above can be concluded that Mathematical connection is the ability of students to (1) recognize equivalent representations of the same topic, (2) relate procedures in one representation to procedures in equivalent representations, and (3) use and appreciate the relationship between mathematics and other disciplines.

Based on the literature review, we make the following hypotheses:

- H1: How is the process and results of developing realistic mathematics learning tools using a good the 4-D development model?
- H2: How is the effectiveness of realistic mathematics learning to improve the ability of middle-school students' mathematical connections?

Methods

This type of study is research and development. The development model used is a 4-D development model from Thiagarajan which includes four stages: designing, designing, developing and disseminating (Thiagarajan, 1974). The sample of this study consisted of VIII-A grade and VIII-B grade from a sampling population of VIII grade with a total of 70 students. The sample for testing the development of learning tools is carried out in VIII-A grade and the sample for the disseminate of learning tools is carried out in VIII-B grade. Learning tools that will be developed in the form of a Lesson Plan, Student Workheet, and Mathematical connection ability test.

The instruments used in this study include instruments to assess the validity, reliability, and effectiveness of the learning tools developed. Data collection tools used in the form of observation sheets, student questionnaire responses, and tests. The mathematical connection ability test sheet consisted of 4 questions about prism material. The observation sheet consists of observing teacher activities and student activities to see student activities during the lesson. A student response questionnaire is used to obtain student responses to the devices that have been used during the lesson. Before conducting research, test instruments, observation sheets, and student response questionnaires were validated by experts consisting of 2 lecturers and 1 mathematics teacher.

The empirical validity tests the ability tests of mathematical connections. Before being used for field trials, mathematics test items were tested outside the research subject to measure validity and reliability. To measure the validity of the item can use the formula product-moment correlation (Arikunto, 2012) follows.

$$\mathrm{r}_{\mathrm{xy}} = \frac{n\sum_{i=1}^{n} x_{ij} y_i - \left(\sum_{i=1}^{n} x_{ij} \sum_{i=1}^{n} y_i\right)}{\sqrt{\left\{n\sum_{i=1}^{n} x_{ij}^2 - \left(\sum_{i=1}^{n} x_{ij}\right)^2\right\}.\left\{n\sum_{i=1}^{n} y_i^2 - \left(\sum_{i=1}^{n} y_i\right)^2\right\}}}, \qquad (1)$$

The value of the validity coefficient is said to be valid if the validity coefficient ranges from +1.00 to -1.00 (Fraenkel, Wallen, & Hyun, 2011).

The calculate the reliability coefficient of test item items using the Alpha-Cronbach formula (Urbina, 2004) as follows.

$$\mathrm{r}_{11} = \left(\frac{n}{n-1}\right)\left(1 - \frac{\sum_{i=1}^{n} \sigma_i^2}{\sigma_t^2}\right), \qquad (2)$$

According to Streiner (2003), "The instrument is said to be reliable if the Alfa Cronbach reliability coefficient is more than 0.70 (ri> 0.70) and the Alfa Cronbach reliability coefficient is not maybe more than 0.90 (ri <0.9) ". Furthermore, to determining improvement students' mathematical connection ability on prism material, the calculation results are further categorized and matched with an interpretation based on the criteria in Table 1 follows.

Table 1: N-Gain Value Criteria

N-Gain	Criteria
$(<g>) \geq 0.70$	"High-g"
$0,30 \leq (<g>) < 0.70$	"Medium-g"
$(<g>) \leq 0.30$	"Low-g"

Sources: (Hake, 1999)

Learning devices are said to be good if they can support learning so that the expected goals can be achieved. In this study, a learning device is said to be good if it meets valid, practical, and effective criteria. This is supported by the statement that "The component of material should be based on state of the art knowledge (content validity) and all components should be consistently linked to each other (construct validity), a second characteristic of high quality materials is that teachers (and other experts) consider the materials to be usable and that it is easy for teachers and students to use the materials in a way that is largely compatible with the developers' attention, the third characteristic of high-quality materials is that students appreciate the learning program and that desired learning takes place. With such effective materials, consistency exists between the intended and experiential curriculum and the intended and the attained curriculum ”(Nieveen, 1999).

The effectiveness of learning in this study is as a benchmark for the success of learning marked by the activities of the teacher managing learning to meet good criteria, student activities meet active criteria, student responses meet positive criteria, and realistic mathematics learning can improve students' mathematical connection abilities achieved. This is following the statement that "Effective learning when students are active is involved in organizing and finding relationships in the information. They encounter rather than being passive recipients of teachers' delegated bodies of knowledge. The activity result not only increases learning and retention of content but also in improved thinking skills ”(Kauchak & Eggen, 2016). Effectiveness answers the question, "To what degree did students accomplish the learning objectives prescribed for each unit of the course?" Measurement of effectiveness can be ascertained from test scores, ratings of projects and performance, and records of observations of learners' behavior (Morrison et al, 2019). This is also in line with the statement that "The effectiveness of learning consists of four indicators, namely quality of instruction, appropriate levels of instruction, intensitive, and time" (Slavin, 2006).

Results and Discussion

A. Description Development of Learning Tools

1. Steps of Defining

Realistic mathematics learning tools to improve students' mathematical connection skills on prism material were developed using the 4-D development model. The learning tools developed in this study include a lesson plan, student worksheets, and a math connection ability test. The process of developing learning tools begins with the defining stage. The results of the analysis at this stage are used to design learning tools at the design stage. The results of the draft at that stage produced draft I.

2. Steps of Designing

Students' mathematical connection ability is measured by developing learning outcomes assessment tools in the form of mathematics connection ability tests on prism material. The test questions on students' mathematical connection skills consist of 4 questions in the form of descriptions. While the Lesson Plan, Student Worksheets, as well as students' mathematical connection ability tests were developed and adapted to the 2013 curriculum.

3. Steps of Developing

After being validated by the validator, the researcher revised the learning by the validator's suggestion that produced Draft II. After all the learning tools meet the valid criteria, then readability tests are carried out on the Lesson Plan, student worksheets, and mathematics connection ability tests. At this stage, the readability test includes the readability test by the partner teacher and the readability test by students. The readability test by the partner teacher says that the learning device can be read and understood clearly. While the readability test by students, three students who were asked to do the readability test stated that in general they could read and understand words or sentences clearly. So that researchers do not revise the Lesson Plan, student worksheets, and tests of mathematical connection ability. Thus it can be stated that the realistic mathematics learning tool developed already meets the criteria of a good learning device and can be used for trials. Based on the eligibility criteria of items that have been described previously, the level of validity of each item is in the medium and high category with the value of the validity coefficient of questions 1 = 0.697, questions 2 = 0.745, questions 3 = 0.862, questions 4 = 0.788. So that each item is said to be valid and feasible to use. While the results of the calculation of the reliability of the test obtained the reliability coefficient value of 0.750. By the specified criteria, so it can be concluded that the testability of mathematical connections has high test reliability so the questions are said to be valid and appropriate to use.

The results of the data analysis show that the score of each aspect of assessment in learning for RPP meetings 1 and 2 is 3 and 4. This value is based on the criteria of the teacher's activity managing learning to meet the criteria well (≥ 3) so that Draft II does not need to be revised. While observing the results of student activities during learning takes place in RPP 1 and RPP 2 achieving a time tolerance contained in the RPP with a tolerance of ≤ 10% based on the ideal time range that has been set because student activities meet active criteria, then Draft II does not need to be revised. Furthermore, based on the results of the student response questionnaire it was found that student responses to each aspect were above 85%, thus based on these values student responses could be said to be positive towards the device and learning. Data on the results of students 'mathematical connection abilities are obtained through the implementation of pretest and posttest are written tests in the form of tests of mathematical connection ability to students which are used to see whether realistic mathematics learning can improve students' mathematical connection abilities. Based on the results of the statistical analysis of the t-test correlated with the right-hand side of the test and the criteria for decision making obtained the results of Tcount <Ttable (-35.42 <1.69) with (DK= n-2) (35-2). These results can be said that the alternative hypothesis (Ha) is accepted and the null hypothesis (H0) is rejected. Thus it can be concluded that there are significant differences (can be generalized) the effectiveness of realistic mathematics learning before and after treatment is given.

Students' mathematical connection ability increases or cannot be known based on the results of the N-Gain analysis. It was found that the percentage of the number of students 62.85% obtained an N-Gain ≥ 0.7 and the percentage of students 37.15% obtained an N-Gain ≥ 0.3. Thus it can be concluded that realistic mathematics learning can improve students' mathematical connection abilities. The recapitulation of the achievement of realistic mathematics learning tool criteria for prism material is presented below.

Table 1. Achievement Criteria for Learning Tools in Classroom Trials

No	Criteria	Aspect	Information
1	Valid	Expert Validation	Valid
		Validity Test	High and Medium
		Reliability Test	High
2	Practical	Teacher activities manage learning	Good
		Student activities	Active
		Student response	Positive
3	Effective	Improvement of Students' Mathematical Connection ability	Achieved

B. Description of the effectiveness of learning

Steps of Disseminating

The dissemination phase is carried out on a limited basis that is, the researcher only distributes it to one class other than the pilot class to determine the effectiveness of learning by using good learning tools produced at the development stage. Data on the results of students 'mathematical connection abilities are obtained through the implementation of pretest and posttest are written tests in the form of tests of mathematical connection ability to students which are used to see whether realistic mathematics learning can improve students' mathematical connection abilities. Based on the results of the statistical analysis of the t-test correlated with the right-hand side of the test and the criteria for decision making obtained the results of Tcount <Ttable (-31.38 <1.69) with (dk n-2) (35-2). These results can be said that the alternative hypothesis (Ha) is accepted and the null hypothesis (H0) is rejected. Thus it can be concluded that there are significant differences (can be generalized) the effectiveness of realistic mathematics learning. Also, based on the results of the N-Gain analysis, it was found that the percentage of students 42.85% obtained an N-Gain ≥ 0.7 and the percentage of students 57.15% obtained an N-Gain ≥ 0.3. Thus it can be concluded that realistic mathematics learning can improve students' mathematical connection skills on prism material.

Based on the description above, realistic mathematics learning on prism material is declared effective, because it meets the following criteria: (a) teacher activities manage to learn well; (b) active student activity; (c) student responses to positive learning; (d) classical learning mastery is achieved; (e) realistic mathematics learning to train students' mathematical connection skills is achieved.

Conclusion

Based on the results of the analysis and discussion, the following conclusions are presented: Realistic mathematics learning tools developed using the 4-D development model meet the criteria of good quality devices, this is indicated by valid, practical, and effective criteria. The learning device is declared valid by the validator. The Mathematical Connection Ability Test meets valid and reliable criteria. Then, teacher activities manage learning well and student activities in active learning. Student also responses to positive learning. Realistic mathematics learning can improve students' mathematical connection abilities achieved.

The effectiveness of realistic mathematics learning is achieved, this is indicated by meeting the following criteria. Teacher activity in learning is good. Then, active student activity and positive student responses. Realistic mathematics learning can improve students' mathematical connection abilities achieved.

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