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The development of student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability of class VII students

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Abstract

The research aims to develop student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability. The type of this research is Research and Development (R&D) by modification models from Sugiyono. The research was carried out through the analysis of potentials and problems, data collection, product design, validation, revision, product trial, and final product. The result of validity test show that student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability are valid with average score 4,67 and practical with average score 3,79. The analysis of pretest and posttest data showed that student worksheets effective to improve mathematical ability with the n-gain score 0,63 on medium category. Therefore, the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability are valid, practical, and effective.

1. Introduction

Mathematics is a discipline that studies how to think and process logic by quantitatively and qualitatively. Mann (2020) said that mathematics is more than a solution of a problem. Mathematics are thinking, exploring patterns and connect to the real world. Besides, mathematics is an applied science that universally in all aspects of human who contribute in various fields.

National Council of Teachers of Mathematics (NCTM) in Jami'atun & Wijayanti (2020) explains that there are five basic skills in mathematics, such as problem solving, reasoning and proof, communication, connection, and representation. These five are very important for students to achieve national education goals. However, in reality these basic ability not fully own by students, especially on mathematical reasoning ability. Nuridawani et al (2015) said that mathematical reasoning ability is one of the main aspects achieved in purpose of mathematics learning, so that mathematical reasoning ability is something that every student must have.

Indonesia's average score on PISA 2018 was ranked seventh from bottom with 78 participants. An average score of Indonesia is 379, which is still far from the international average (489). OECD (2016) reveals that mathematical literacy is an individual's ability to formulate, use and interpret mathematics in various contexts. In mathematical literacy, include mathematical reasoning and understanding mathematical concepts. This shows that mathematical reasoning plays a role on students' mathematical literacy skills.

NCTM in Jami'atun & Wijayanti (2020) explains that reasoning is a process of thinking based on facts from correct assumptions to drawing the conclusion. Safitri & Arnawa (2019) said that mathematical reasoning skill is an individual ability to think logically based on the existed evidences. Therefore, students' mathematical reasoning ability is an important aspect in learning mathematics. Designing a learning

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approach that involves students more on learning process is able to explore their potential and improve mathematical reasoning ability. This is similar with opinion of Henningsen & Stein in Sari (2015) that without being directly involved in earning, students cannot develop their reasoning capacity appropriately.

Based on results of observation and interview with one of mathematics teacher in SMP 33 Semarang, said that the cognitive ability level of students in there was only in level one and level two abilities. Level one include C1 (knowledge) and C2 (understanding). While the second level include C3 (application). The ability of students at level 3 (the ability of reasoning) still low. It can be seen from each daily test that used reasoning questions which require analysis, students still difficult to solve the mathematics problems. The mathematical reasoning ability is still low because the students are not accustomed to dealing with questions that require high-level thinking skills.

One of efforts to improve mathematical reasoning ability is applied learning models that involves students to find concepts. Understanding concepts is priority because understanding is main requirement for having mathematical reasoning ability (Ario, 2016). Guided discovery is one of learning models that make students finding, searching, and discussing something in learning. This learning models focus on student activities while studying. The advantages of guided discovery is teacher directs the students to active in learning to find the concepts from data observed by themselves so that students are able to conclude their own mathematical concepts in general.

Application of learning process also require a communication between teachers and students. To support this, supporting learning resources are needed, student worksheets it might be one. Student worksheets are sheets that contain task and must be done by students (Depdiknas, 2008). To support student have a good study skills, student worksheets are given the nuances of STEM (science, technology, engineering, and mathematics). STEM is important to improve students' scientific attitudes and understanding concepts (Thahir et al, 2020). It hoped by combining students worksheets with aspect in STEM, the learning process can be more effective and efficient.

Based on the description above, researcher interested to conduct research with the tittle "The Development of Student Worksheets Based on Guided Discovery with STEM-nuances to Improve Mathematical Reasoning Ability of Class VII Students"

2. Methods

The type of this research is Research and Development (R&D) method. R&D is a research method used to produce a product and test the effectiveness of the product (Sugiyono, 2016). Product of this research is student worksheets based on guided discovery with STEM-nuances for class VII students. This product arranged to improve mathematical reasoning ability. The steps of this method are (1) potentials and problems; (2) data collection; (3) product design; (4) validation; (5) revision; (6) product trial; (7) final product.

The research was started by potentials and problems to know the problems that happened in the school during the mathematics learning process. The second step was data collection. Researcher did study of literature from old research related to the research. The next step is making design of student worksheets. After finished the design, student worksheets were validated by some validators to know the validity and practicality. Before getting the result, student worksheets that have been validated by validator were revised based on their suggestions and comments. After the product was valid and practical, product being trialed to know the effectiveness from student worksheets. The last step is final product, student worksheets has been valid, practical, and effective to improve students' mathematical reasoning ability. After that, the data analysis technique used are validity test, practicality test, and effectiveness test.

The data analysis technique for the validity of student worksheets use the following formula.

$$VR = \frac{\sum x}{n}$$

Where,

VR : average score of validity

$\sum x$: total score

n : number of category

The criteria for the validity of student worksheets in this study based on Khabibah (Wicaksono et al, 2014) are shown in Table 2.1 below.

Table 2.1 Criteria of Validity

Score Interval	Category
$4{,}00 \leq VR \leq 5{,}00$	Very Good
$3{,}00 \leq VR < 4{,}00$	Valid
$2{,}00 \leq VR < 3{,}00$	Enough
$1{,}00 \leq VR < 2{,}00$	Not Valid

Student worksheets based on guided discovery with STEM-nuances are said valid if the average total of validators' score is in the valid or very good category.

The data analysis technique for testing the practicality of student worksheets use the following formula.

$$R = \frac{total\ score\ obtained}{maximum\ total\ score}$$

The criteria for the practicality of student worksheets in this study are shown in Table 2.2 below.

Table 2.2 Criteria of Practicality

Score Interval	Category
$3{,}25 \leq R \leq 4{,}00$	Very Good
$2{,}50 \leq R < 3{,}25$	Good
$1{,}75 \leq R < 2{,}50$	Enough
$1{,}00 \leq R < 1{,}75$	Less

R = average of teachers' actual score

Student worksheets based on guided discovery with STEM-nuances are said practical if the results of the teachers' response are at least in the good category.

The data analysis technique for testing the effectiveness of student worksheets described as follows.

1) Normality test
   Normality test aims to determine whether the data that we get comes from a population that is normally distributed or not. In this study, normality of the data was tested using the Kolmogorov-Smirnov test with SPSS 22 software's help.
2) Average completeness test
   Average completeness test aims to determine the average student learning outcomes after using the student worksheets reach the minimum submission criteria at SMP 33 Semarang for mathematics subject (70). This test uses one-sided average test (right).
3) Classical completeness test
   Classical completeness test used to determine whether the proportion of completeness mathematical reasoning ability test results reaches 75% of student or more. This test uses the right side proportion test.
4) N-Gain test
   N-Gain test used to measure the improvement of mathematical reasoning ability by using the results of pretest and posttest in class that used the student worksheets.

$$Normalized\ Gain\ (g) = \frac{posttest\ score - pretest\ score}{max\ score - pretest\ score}$$

According to Lestari & Yudhanegara (2015), the criteria of n-gain score are shown in table 2.3.

Table 2.3 Criteria of N-Gain Score

N-Gain Score	Criteria
$0{,}70 \leq (g) \leq 1{,}00$	High
$0{,}30 \leq (g) < 0{,}70$	Medium
$0{,}00 \leq (g) < 0{,}30$	Low
$(g) = 0$	Constant
$-1{,}00 \leq (g) < 0{,}00$	Decrease

3. Results & Discussions

3.1. Potentials and Problems

Researcher had interview with a mathematics teacher at SMP 33 Semarang to know the mathematical reasoning ability and mathematic learning in class. The problems that exist in SMP 33 Semarang are the

students' mathematical reasoning ability which is still weak that can be seen from the results of students' examination on previous semester, the lack of student motivation to learn mathematics, and the learning tools used have not fulfilled the needs of student. So far students only use student handbook that causes students get bored quickly because they feel difficult to understand the meaning of the book. Therefore, the students need for learning tools which contains activities that involve students to find the concept and making students feel more challenged during the learning process.

3.2. Data Collection

In this step, researcher did analysis of some old research related to the research to get information about student learning resources, especially student worksheets. Nurrahmah & Suhendar (2017) said that learning process using student worksheets can improve student learning outcomes in mathematics. In Putra et al (2018) conclude that by using student worksheets based on guided discovery can be used to improve conceptual understanding and students' mathematical reasoning ability. After analized the previous studies, in this step researcher also carried out the needs analysis which include analysis of Main Competencies, Basic Competencies, Competency Achievement Indicators, chapter used, and characteristic of student worksheets that refer to syntax of guided discovery model.

3.3. Product Design

The next step is making product design of student worksheets based on guided discovery with STEM-nuances. Before making student worksheets, researcher arrange the map of student worksheets. Draft of student worksheets are made and then given suggestions by lecture. The student worksheets based on guided discovery model and given the STEM nuances on the problems listed on the student worksheets. After that, student worksheets are customized by indicator of mathematical reasoning ability. There are six worksheets created with Microsoft Word software to arrange the material and Coreldraw X7 software to design the student worksheets layout. The examples of the display of student worksheets are shown on figure 3.1 and 3.2

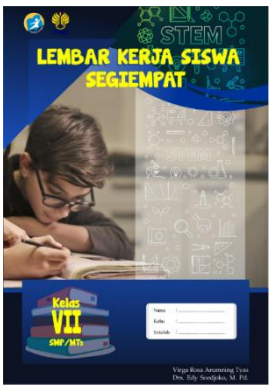

Figure 3.1 Cover of Student Worksheets

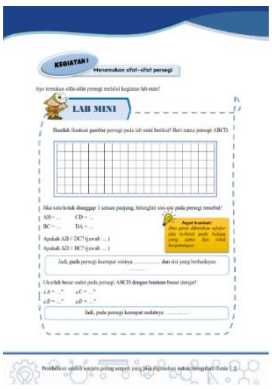

Figure 3.2 Example of Content from Student Worksheets

3.4. Design Validation

The design of student worksheets product that had been made then tested for validity, that is validity test and practicality test by validators to find out the quality of student worksheets. The validators will be given a validation' sheet to measure the validity of the modified student worksheets according to research purposes.

3.4.1. Validity Test Results of Student Worksheets

Validity test aims to determine the level of validity of the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability. The level of validity are assessed based on aspects in validation' sheet, including (1) the content feasibility; (2) linguistic feasibility; (3) presentation feasibility; (4) graphical feasibility. Student worksheets will be assessed by four validators. Recapitulation of validation results are presented in table 3.1.

Table 3.1 Validity Test Result

Validator	Institute	Scores	Criteria
Validator 1	UNNES	4,93	Very Good
Validator 2	UNNES	4,5	Very Good
Validator 3	SMP 33 Semarang	4,96	Very Good
Validator 4	SMP 33 Semarang	4,3	Very Good
Average Score		**4,67**	**Very Good**

Based on criteria of validity, student worksheets based on guided discovery with STEM-nuances included on very good category with an average score 4,67. Therefore, the student worksheets can be used in learning with some revisions according to the validator's suggestions.

3.4.2. Practicality Test Results of Student Worksheets

Practicality test of student worksheets aims to determine the level of practicality of the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability. In this study, this practicality test is taken from the responses of two mathematics teachers at SMP 33 Semarang to the student worksheets that have been developed. The results of the practicality test of student worksheets are presented in table 3.2.

Tabel 3.2 Practicality Test Result

Respondent	Scores	Category
Teacher 1	3.83	Very good
Teacher 2	3.75	Very good
Average	**3.79**	**Very good**

Based on practicality test results, the average score is 3,79 with very good category. Its shows the student worksheets that have been developed are practical. Ana (2020) states that student worksheets that have been developed are easy to understand for teachers and students during learning in the classroom. Therefore, the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability are practical and can be used in mathematics learning.

3.5. Product Trial

In this step, the researcher did the effectiveness test of student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability. Learning process are applied to class 7I SMP 33 Semarang by WhatsApp and Google Meet applications.

1) Normality test

Before questions of pretest and posttest given to students of class 7I SMP 33 Semarang, the question are tested first in class 7H SMP 33 Semarang. The test results about mathematical reasoning ability were analysed for validity, reliability, discriminatory power, and level of difficulty. The results can be seen in table 3.3 below.

Table 3.3 Test Results on Mathematical Reasoning Ability

Question Number	Validity	Reliability	Discriminatory Power	Difficulty Level
1	Valid (0,617)	High (0,74)	Good (0,46)	Medium (0,66)
2	Valid (0,771)		Good (0,51)	Medium (0,64)
3	Valid (0,711)		Good (0,47)	Medium (0,61)
4	Valid (0,686)		Not Good (0,20)	Medium (0,60)
5	Valid (0,744)		Good (0,43)	Medium (0,47)
6	Valid (0,785)		Enough (0,36)	Medium (0,43)
7	Valid (0,447)		Not Good (0,17)	Medium (0,58)
8	Valid (0,841)		Good (0,54)	Medium (0,42)

Normality of pretest and posttest used SPSS 22 software's help. Based on calculations, the value of Sig. of pretest is 0,172 and value of Sig. of posttest is 0,200. Because the value of Sig. > 0,05, it can be concluded that the pretest and posttest data are normally distributed.

2) Average completeness test

Based on calculations, the value of t_{count} = 5,24 and t_{table} = 1,7. Because $t_{count} > t_{table}$, it means the average student learning outcomes after using the student worksheets is more than 70. Annajmi & Azmi (2017) said that role of students in learning using the guided discovery model are big, so the

teachers is not as the main role. In the other words, students play an important role in learning so they are able to construct their own knowledge. So the student worksheets based on guided discovery with STEM-nuances are able to help students to beyond the average completeness and purpose of learning can be achieved.

3) Classical completeness test

Based on calculations, the value of z_{count} = 1,78 and z_{table} = 1,64. Because $z_{count} > z_{table}$, it means the proportion of completeness mathematical reasoning ability test results is more than 75% of student. Annajmi & Azmi (2017) explains that by using student worksheets based on guided discover method students will actively seek, organize their own knowledge, and create conclusions from their knowledge with the instructions and guidance of the teacher. Putra et al (2019) said that by using guided discovery model there are two-way system that involves students to answering questions from the teacher. Therefore, the student worksheets based on guided discovery with STEM-nuances can help students to achieve the classical completeness.

4) N-Gain test

The improvement of mathematical reasoning ability measured with a written test that refers to indicator of mathematical reasoning ability. The n-gain test results can be seen in table 3.4 below.

Table 3.4 N-Gain Test Results

Average Score		N-Gain	Criteria
Pretest	Posttest		
50,85	81,63	0,63	Medium

Based on table 3.4, get the n-gain test results is 0,63. It indicates that an improvement average score of pretest to posttest is 0,63 with medium criteria. The improvement in medium criteria because each student has different abilities. There were students with low and high level ability. Students with low level had a significant improvement in mathematical reasoning ability. Meanwhile, for students with high level had a small improvement because they have high mathematical reasoning ability before. Therefore, classically the classes with learning using student worksheets had an improvement mathematical reasoning ability in medium criteria. At learning by using student worksheets based on guided discovery with STEM-nuances, students are encouraged to think independently on finding a concept according to instructions in student worksheets.

The n-gain test also viewed by the indicator of mathematical reasoning ability, presented in figure 3.3 below.

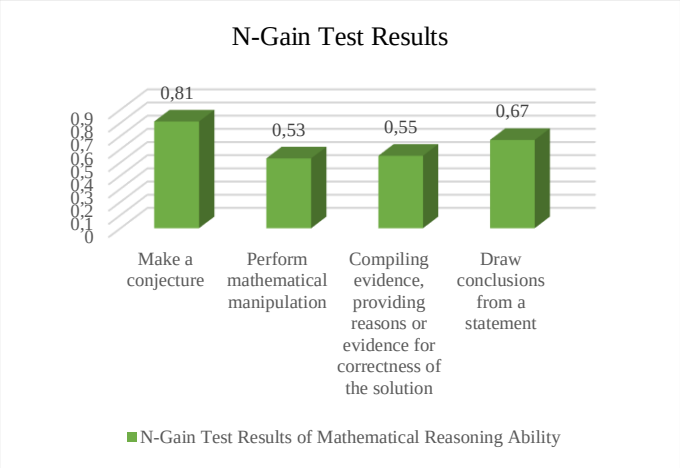

Figure 3.3 N-Gain Test Result on Indicator of Mathematical Reasoning Ability

Based on figure 3.3, the improvement of indicator make a conjecture is 0,81 in high criteria; perform mathematical manipulation is 0,53 in medium criteria; compiling evidence, providing reasons or evidence for correctness of the solution is 0,55 in medium criteria; and draw conclusions from a statement is 0,67 in medium criteria.

These results indicate that the student worksheets based on guided discovery with STEM-nuances can improve the mathematical reasoning ability. It same with the research by Sari (2015) that the mathematical reasoning ability of students who obtain learning materials through guided discovery model can improve. Furthermore, it supported by research of Putra et al (2018) which states that

learning which involves students' activeness to finding the concept independently can improve mathematical reasoning ability. Because the learning activities focus on student-center activities that make learning more meaningful and able for a long time, so the student worksheets based on guided discovery with STEM-nuances are effective to improve students' mathematical reasoning ability.

3.6. Final Product

The final product in this study is a student worksheets based on guided discovery with STEM-nuances that is valid, practical, and effective to improve students' mathematical reasoning ability. This student worksheets is structured based on the syntax of guided discovery model and refers to indicator of mathematical reasoning ability. Compiled by six worksheets containing quadrilateral material, including square, rectangle, parallelogram, trapezoid, rhombus, and kites.
add

4. Conclusion

Based on the results of the research and discussion previously described, it can be concluded that.

- The validity test of student worksheets gets an average score 4,67. It shows that the student worksheets have been developed in very good category. Thus, the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability are valid.
- The practicality test of student worksheets gets an average score 3,79. It shows that the student worksheets have been developed in very good category. Thus, the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability are practical.
- The effectiveness test of student worksheets show that: the average test results of students' mathematical reasoning ability are more than minimum submission criteria (>70); the proportion of completeness of mathematical reasoning ability test results is more than 75%; and the n-gain test results is 0,63 with medium criteria, so there is an improvement of mathematical reasoning ability. Thus, the student worksheets based on guided discovery with STEM-nuances to improve mathematical reasoning ability are effective.

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