The development of student worksheets based on metacognitive approach to improve students’ mathematical representation ability

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Abstract. Mathematical representation ability is an important mathematical skill. It can be trained by using a student worksheet as a learning resource. This research aimed to develop and produce valid, practical, and effective student worksheets which were based on metacognitive approach to improve students’ mathematical representation ability. This research used the 4-D model (Define, Design, Development, and Disseminate). This research was conducted at a secondary school in Pekanbaru, Indonesia. The research participants were seventh-grade students at the school. Data collection instruments were questionnaires and mathematical representation ability test. Data were analyzed using descriptive statistical analysis technique. The result showed that the worksheets were very valid, very practical and very effective. The validity rate was of 81.71%, the practicality rate was 82.30% and the effectiveness rate was 83.33%. Hence the worksheets can be used in mathematics learning to improve student’s mathematical representation ability.

1. Introduction

The abilities to be achieved in the process of learning mathematics according to National Council of Teachers of Mathematics (NCTM) are reasoning, communicating, connecting, representing and problem solving [1]. The ability of mathematical representation is very important because it can be used to represent a situation or problem in order to facilitate the search for a solution. The success of problem solving depends on: (1) the ability to represent problems such as constructing and using mathematical representation in words, graphs, tables and equations; (2) problem solving skill; and (3) the ability to manipulate symbols [2-3]. Some representations are more concrete than others. A concrete representation can be used as a reference for a more abstract concept and as a tool in problem-solving [4-5].

Mathematical representation is everything that a student make to internalize and show their work [4]. Student-made representations are expression of their understanding of a mathematical concept or idea that they use in finding a solution to a mathematical problem [1]. A student can communicate his or her ideas for a mathematical strategy or solution in various ways of representation: (1) symbolically (numerical and/or algebraic symbols); (2) verbally; and (3) visually in the forms of diagrams, graphs or tables [2].

The quality of learning needs to be improved by applying various approaches. One of the recommended approaches for mathematics learning is the metacognitive approach. Learning with a metacognitive approach is a learning that instills awareness to students about a process of how to
design, monitor, and evaluate the activities undertaken to determine the solution of a problem. Metacognitive approach can be done by: (1) asking questions and facilitating the students so that the students can control their thinking process and activity, choose appropriate problem-solving strategies, assess their work, not give up easily, reflect and re-check their problem-solving activities; (2) asking the students to analyze their peers’ answers; (3) giving rewards to students for their performances; (4) asking the students to keep a diary or journal to record their learning experience; and (5) modeling metacognitive behavior in learning [6-8].

According to Wara [9], metacognitive approach in mathematics learning can be applied by adopting the Meyer model through the following three stages.

1.1. First stage: Initial discussion
At this stage, the teacher explains the general purpose of the topic. The students are encouraged to think by answering metacognitive questions listed in the student worksheet. Students are guided to instill awareness by asking themselves when answering the questions. At the end of understanding the concept, the students are expected to understand all the material descriptions and be aware of what they have done, how they did it, which parts they did not understand, what questions are left unanswered and how to find solutions to them.

1.2. Second stage: Students work independently to solve problems
The students are given a set of problems asked to do it individually. The teacher walks around the classroom and provides interpersonal feedback. The teacher helps the students keep an eye on their thinking, not just giving the right answers when the students make mistakes.

1.3. Third stage: conclusion
The inference made by the students is a recapitulation of what is done in class.

Learning process is an important thing that should lead to students’ mastery of learning objectives. To facilitate learning, the teacher can facilitate with teaching materials such as a student worksheet. Unfortunately, student worksheets are not yet widely used by teachers in most secondary schools in Pekanbaru. Therefore, it is necessary to develop a student worksheet to be used in Pekanbaru in order to create a meaningful learning process and in accordance with the provisions of the curriculum. This will give students the opportunity to construct knowledge by engaging in active thinking activities.

Based on the explanation above, the researchers conducted a research related to the development of student worksheets which were based on metacognitive approach to improve the mathematical representation of secondary school students. The question addressed in the research was: How were the validity, practicality, and effectiveness rates of the student worksheets which were developed based on metacognitive approach to improve students’ mathematical representation ability in the topics of one-variable linear equations and linear inequalities for grade 7 students in Pekanbaru?

2. Method
The type of this research was research development using the 4-D development model. The 4-D model was developed by Thiagarajan and it consisted of Define, Design, Development and Dissemination [10]. In this research, the dissemination stage was not done because of time and cost constraints. The participants of the study were grade 7 students at a secondary school in Pekanbaru. The products were student worksheets focusing on the topics of one-variable linear equations and linear inequalities. The worksheets were developed to improve students’ mathematical representation ability. This research was conducted during the odd semester of the academic year 2017/2018.

At the validation stage, the student worksheets were validated by mathematics experts, learning design experts and teachers. After being declared valid, the worksheets were piloted into a small group consisting of 12 students which were divided into three groups. These three groups were heterogeneous in terms of ability and gender. They learned using the student worksheets. After the small group trial,
revisions were made. Then, the worksheets were tested in large groups. Large group trials were conducted in another class consisted of 36 students. This trial was done to determine the practicality level of the worksheets. More revisions were made after the large group trial. The effectiveness test was done with yet another class. This class was divided into two groups, one group was taught using the designed student worksheets and the other group without the worksheets.

The instruments in this research were validation sheet, questionnaires for practicality test and a set of tests. The validation sheet was designed to validate the products. For the practicality test, we used questionnaires which were administered to investigate students and the teachers’ perceptions on the implementation of the products. The effectiveness of the products was assessed using a set of tests in order to gain data about the students’ mathematical representation ability after using the worksheets. Data were analyzed by using descriptive statistical analysis method.

3. Result and discussion
The result of the development research was student worksheets for grade seven on the topics of one-variable linear equations and linear inequalities. The development model that was used in the development of the products was the 4-D model. The stages were as follows.

3.1. Define
This stage aimed to define the terms of the implementation of learning using student worksheet that would be developed. The steps consisted at this stage included curriculum analysis, student characteristics analysis, material analysis and objectives.

At the stage of curriculum analysis, the researchers established basic competencies that were required by the curriculum, they were: students able to explain the definition of a one-variable linear equation and a linear inequality; and students able to solve problems related to one-variable linear equations and linear inequalities.

In the analysis phase of the students’ characteristic, researchers reviewed the level of students’ cognitive development and looked at the skills of the students both individually and in groups. The findings of this stage were: (1) the students’ mathematics ability could be classified as medium, (2) the teaching and learning in the classroom tended to be passive where the students, most of the time, listened to teacher’s explanation; (3) when the students were divided into groups, they chose their group members which led to monogenous groups; (4) students tended to memorize the formula without understanding the concept so they usually found difficulties in solving problems. These data indicated that the students were qualified to participate for the limited and field trials.

In the material analysis stage, the researchers analyzed the scope of the material based on the required basic competencies as stated in the curriculum. The subtopics of linear equations and linear inequalities were: closed and open sentences; one-variable linear equation; the equivalent form of a linear equation of one variable; and one-variable-linear inequalities. These subtopics were then formulated into several indicators of learning achievement as follows: (1) able to explain the meaning of closed sentences and open sentences; (2) able to distinguish between closed sentences and open sentences; (3) able to determine open or closed sentences of everyday problems; (4) able to find the concept of one-variable linear equation; (5) able to solve problems related to one-variable linear equations; (6) able to determine the equivalent form of a one-variable linear equation; (7) able to solve problems related to one-variable linear equation and linear inequality; (8) able to find the concept of one-variable linear inequality; and (9) solve problem of one-variable linear inequality.

3.2. Design
At the design stage, the researchers compiled four student worksheets to be delivered in four meetings. The student worksheets were structured to include five components: title, discourse, study guide, work steps, and task. Student worksheet was designed in such a way in accordance with the metacognitive approach. The first worksheet was referred to as Student worksheet (SW-1) as shown in figure 1. Figure 1 shows 1 out of 5 pages of SW-1.
Figure 1. Student worksheet-1.

Figure 1 is page 1 of SW-1. It contains the initial discussion stage. In this stage the students were asked to pay close attention to a dialog and determine whether the sentences were true, false or neither. This discussion was intended to lead the students to construct their understanding about close and open sentences. This stage served as a basis for the next independently and conclusion stages.
3.3. Develop
At the develop stage, the researchers conducted the validity, practicality, and effectiveness test.

3.3.1. Validity test. The student worksheet that had been designed were then validated by the validators using validation sheet and through discussion. Validity test by material experts were conducted to examine the material aspects, objectives, and metacognitive approach. Validity test by design and learning experts was aimed to assess the writing construction aspect, language used, worksheet display and image placements. The validators’ suggestions were used to revise or improve the worksheets. Table 1 shows the validation result.

Based on the validation results as shown in table 1, the validity of the worksheets fell into very valid criteria with the average percentage of 81.71%. This indicated that the worksheets were feasible to be used in learning and could be used in the practicality test.

| No | Aspect                        | Validity score | Criteria       |
|----|-------------------------------|----------------|----------------|
| 1  | Presentation of goals         | 79.85%         | Valid          |
| 2  | Metacognitive approach        | 80%            | Valid          |
| 3  | Material truth                | 81.5%          | Very valid     |
| 4  | Mathematical representation ability | 84%     | Very valid     |
| 5  | Construction                  | 83.57%         | Very valid     |
| 6  | Language                      | 81.67%         | Very valid     |
| 7  | Display                       | 81.43%         | Very valid     |
|    | Average percentage            | 81.71%         | Very valid     |

3.3.2. Practicality test. Practical test was done after the validation process had been completed and the worksheets had been declared valid. The practicality test was conducted to find out whether the worksheets were practical or easy to use by students as users. The practicality test involved two classes of students at a secondary school in Pekanbaru.

3.3.2.1. Practicality test on small group (limited). A small group test was conducted to see if there were errors and deficiencies in the worksheets found by the students. The small group test involved 12 students from class 1. Table 2 shows the results of the practicality test during small group testing.

| No | Variable of practicality                  | Practicality score | Criteria      |
|----|------------------------------------------|--------------------|---------------|
| 1  | Students’ interest                        | 84.26%             | Very practical|
| 2  | Student worksheet display                 | 85.15%             | Very practical|
| 3  | Process of use                            | 81.16%             | Very practical|
| 4  | Metacognitive approach                    | 80%                | Practical     |
| 5  | Students’ mathematical representation ability | 79.81%          | Practical     |
|    | Average                                   | 82.08%             | Very practical|

Based on table 2, it could be seen that the overall percentage of the students’ ratings suggested that the worksheets were very practical. The overall practical score was 82.08%.

3.3.2.2. Practicality test on large group. The student worksheets based on metacognitive approach which had been declared practical during the small group test, were then tested in a large group test (field trial). This involved 36 students of class 2. After being taught using the worksheets, the students were asked to give their perceptions on the worksheets using a questionnaire. Table 3 shows the result of the practicality test on large group trial.
It could be seen in table 3 that the overall percentage of the students’ ratings suggested that the worksheets were very practical. The overall practical score was 82.52%.

Table 3. Practicality test result on large group.

| No | Variable of practicality                       | Practicality Score | Criteria     |
|----|-----------------------------------------------|--------------------|--------------|
| 1  | Students’ interest                            | 85.36%             | Very practical |
| 2  | Student worksheet display                      | 84.15%             | Very practical |
| 3  | Process of use                                | 82.14%             | Very practical |
| 4  | Metacognitive approach                         | 81.12%             | Very practical |
| 5  | Students’ mathematical representation ability  | 79.81%             | Practical     |
|    | Average                                       | 82.52%             | Very practical |

3.3.3. Effectiveness test. Analysis of effectiveness was based on students’ test results after being taught using the worksheets. The worksheets were designed to train the students’ individual noticing ability to solve problems and to be able to answer metacognitive questions. These questions were meant to become a trigger for the students’ metacognitive activity in problem-solving. Teacher gave feedback interpersonally to students so that they could correct their mistakes in solving problems. The test results showed that 83.33% students passed the test.

4. Conclusion
The result showed that the worksheets which were based on metacognitive approach were very valid with the validity rate of 81.71%, very practical with the practicality rate of 82.30%, and very effective with the effectiveness rate of 83.33%. Therefore, this research had produced student worksheets which were valid, practical, and effective.

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