Development of student worksheets based on problem-based learning in the algebra topics

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Abstract. This research uses design research type development study method which aims to develop worksheets based on problem based learning algebraic operating materials that are valid and practical. This study focuses on 2 stages, namely the preliminary stage and formative evaluation which includes self-evaluation, one-to-one, small group. The research subjects were 7th grade students in junior high school in developing. The results of this research are valid and practical problem-based student worksheets. Validity can be seen from the results of expert assessments and one-to-one stages. Practicality can be seen from students' skills when understanding and completing student worksheets at the small group stage.

1. Introduction
Algebra is one of the materials studied by all educational level, including 7th grade students of junior high school. The use of algebra is easily found in daily life. For example, a simple counting to find a specific price of a product or setting time alarm so one student doesn’t late to go to school, to more complex ones like finding an appropriate equation to approximate Ronaldo’s infamous “rainbow goal” or launch a rocket that landed precisely on the moon. The importance of algebra not limited in mathematics discipline, but also other areas like physics, chemistry, and accounting [1]. Without it, ones will not be able to control their financial issue or comprehend particular chemistry and physics concepts. In more cognitive use, algebra helps someone to think logically and critically [2, 3]. Despite of these advantage I mastering algebra, many students have difficulty solving algebra problems related to daily life [4]. The difficulty of students in solving problems about algebra is because students do not understand the concepts and principles associated with algebraic definitions and operations [5]. Evidently, the result of a test that apply algebra as one of the mathematics test material, PISA, has put Indonesia at 72nd rank out of 78 participating countries, with mathematics score 379, below the average score 489 [6]. Since this test emphasizes on measuring the ability of higher order thinking skills (HOTS), such as problem solving, critical thinking, analysis, reasoning, and literation, this result means that Indonesia’s students are lack of the ability to reason, communicate, examine, and solve problem [7].

Many factors can cause this result. First, the instructional process doesn’t allow students to improve their higher order thinking skill [8]. Most teachers in Indonesia still employ direct learning that focuses on achieving good result in national exam (UN) rather than developing students’ HOTS [9]. Second, the teaching material, like books, student’s worksheet or module, is not appropriate to help students enhance their higher order thinking skills [10, 11].

To overcome student difficulties in solving these problems, teachers must understand student difficulties and then be able to determine appropriate learning strategies in order to make learning more meaningful for students [12]. One of the student-centred learning model that using problems as learning
is problem based learning [13, 14]. Problem based learning is a learning model that provides real-world problems, where students are encouraged to use their scientific reasoning skills to solve problems [15, 16]. Problem based learning is a curriculum development and teaching approach consisting of carefully selected problems designed to require students to increase critical knowledge, problem-solving skills, independent learning strategies, and team participation skills [17, 18]. One of the features in problem based learning that support student’s HOTS is the use of ill-structured problem [8]. Through ill-structured problem, students have the space to investigate and evaluate certain condition and solution towards the problems, assumption, and mathematics concepts [8, 19].

One of the strategies to help students understand and apply concepts is through well-designed activity and the use of student worksheets [15, 20]. Student worksheets that are designed must make students accustomed to solve problems like problem based learning [21]. Hence, based on those analysis, the purpose of this research are to develop student worksheets characterized by problem based learning model in algebraic material and describe the developing process from prototyping phase to small group testing.

2. Method

This study is a design research method with the type of development study this research focuses on 2 stages, preliminary and formative evaluation [22, 23, 24]. Data collection techniques are walkthrough, documentation, observation and interview. The subject of this study were 7th grade student at junior high school in Palembang.

In the preliminary stage, there are analysis on research subject, algebraic material, theoretical framework of problem based learning, and designing student worksheet based on problem based learning activity. Formative evaluation consisted of self-evaluation, expert review, one-to-one, and small group test. In self-evaluation stage, the researcher evaluates and reviews the initial design of the student worksheet to go to prototype 1. In the expert review stage, prototype 1 is validated by experts by assessing and evaluating the content, construct and language of the prototype. One-to-one is done on 3 7th grade students. After the expert reviews and one-to-one stages, prototype 1 will produce a valid prototype 2. Which will then proceed to the small group stage to see the practicality of the developed worksheets.

3. Result and Discussion

3.1. Preliminary phase

The preliminary phase includes the analysis phase and the design phase. At this stage, an analysis of the research subject is assisted by the mathematics subject teacher to determine the students involved in the study. This resulted in choosing 3 students to be involved in one-to-one phase, and 6 students small group phase. An analysis related to literature study was carried out as a focus in this study in the form of algebraic operating material adjusted to the learning objectives and the syntax of the problem based learning [25, 26]. Then designed student worksheets in accordance with the syntax of problem based learning which is shown in Table 1.

The material in the developed student worksheet developed contained 2 problems regarding the addition and subtraction forms of algebra.

3.2. Formative Evaluation

3.2.1. Self-Evaluation

In the self-evaluation stage, an evaluation of the student worksheets is performed independently and looks at the student worksheets that have been designed in terms of content, construct and language. The results obtained from this stage are prototype 1 which next will be validated through expert reviews and one-to-one stages. Student worksheets created at the self-evaluation stage are shown in Figure 1.
Table 1. Framework of Problem based learning in student worksheet

| Syntax                        | Thinking Ability                                                                 |
|-------------------------------|----------------------------------------------------------------------------------|
| Giving a problem              | Interpreting information from verbal, nonverbal, picture or graphic statements.  |
| Fact Clarification            | Identify or formulate questions of a problem.                                    |
| Defining problem              | Designing problem solving procedures.                                            |
| Creating plan to solve problem| Apply the problem solving plan.                                                  |
| Investigation                 | Reveal the results of the investigation clearly.                                 |
| Sharing information           | Apply the problem solving plan.                                                  |
| Solving problem               | Provide solutions that are consistent with all known facts and proposed problems.|
| Presenting the solution       | Express solutions in verbal representations, drawings, or graphics accurately.    |
|                               | Evaluate solutions provided by others using logical procedures and valid criteria.|

![Figure 1. prototype 1](image)

3.2.2. Expert Reviews and one-to-one

After going through the self-evaluation stage, researchers conducted an expert review and one-to-one stages, where these stages were conducted to see the validity of the student worksheets. The expert review stage was validated by the mathematics lecturers of Sriwijaya University. Experts evaluated the worksheets in terms of content, construct and language.

Along with an expert review, student worksheets were tested on a one-to-one stage. In this stage, student worksheets are tested by 3 seventh grade students. These subjects were asked to work on the
problems contained in the student worksheet and then students will be asked about opinions, suggestions and comments about the problems in the worksheet. Table 2 shows comments/suggestions from validators and students, as well as the decision to revise the student worksheets.

From the results of comments/suggestions from experts and students, there were improvements to the student worksheet including improving the layout of the study instructions and fixing the 2 problems that were on the student worksheet. Based on the results of comments and opinions provided by experts and students, it can be concluded that prototype 2 is said to be valid. A valid prototype 2 can be found in Figure 2.

Table 2. Comments/suggestions

| Validators | Comments/ Suggestions | Revision |
|------------|-----------------------|----------|
| Mathematics lecturers | 1. The problems in the student worksheet are in accordance with the material and in accordance with the stages of problem based learning 2. Improve the layout of writing and spelling on student worksheets | 1. Improved spelling and layout of writing on student worksheets |
| Students | 1. Students feel problem 2 on the student worksheet is too long and complicated |

Figure 2. the results of revisions in the one-to-one and expert reviews

3.3. Small group

The small group stage is conducted to see the practicality of the student worksheets that are being developed. The practicality emphasize on the legibility of the developed worksheet [27]. To see this legibility, the researchers picked 6 seventh graders as the subjects based on mathematics teacher’s suggestion. These 6 subjects consisted of 2 higher ability students, 2 moderate ability students, and 2 lower ability students. These subjects were asked to solve all the problem of the worksheet and then being interviewed to see their responds toward the worksheets. Based on the interview, it can be concluded that students’ responds toward the worksheet is positive, which means there is no need of significant changes towards prototype 2.
Besides that, the researchers also assessed students’ answers to see if they can understand and solve the problem without any obstacle, especially in term of the language and the clarity of the illustrations. Figure 3 and Figure 4 are example of the answer from one of the students at the small group stage.

In Figure 3 and 4 it can be seen that the student can understand the given problem. Students take the number of pempek in the box in problem 1 and the number of egg boards in problem 2 using variables. Students can find out Rani’s total order in problem 1 and Pak Raden’s egg shortage in problem 2. From the student’s answer to problem 2 it appears that students are not accustomed to checking the answers obtained. This is because students are not used to evaluate their own solution and see if the solutions are consistent with the given problem, conditions, assumptions, or certain mathematical concepts [8].

However, all three groups were able to re-examine the answers they had obtained, although it took more time to understand the meaning of “checking” the answers.

Figure 3. student answers on the student worksheet in the first problem

Figure 4. student answers on the student worksheet in the second problem
The results of the analysis of students' answers show that students can solve the problems from student worksheet correctly. This means that there is no significant problem regarding the clarity of language and figures. Therefore, the prototype 2 satisfy the criteria of legibility and hence, practical.

4. Conclusion
This study has produced student worksheets based on problem-based learning that is valid and practical. Validity student worksheets can be seen from the assessment of the content, construct, and language as well as comments and opinions from the one-to-one stage regarding the clarity of the problems contained on the student worksheet. Practicality student worksheet can be seen from the small group stage, that student can understand the problem and answer correctly. Therefore, this product is eligible to be tested in field test to see if this product is effective to measure student’s HOTS.

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