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The development of constructivism-based student worksheets

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Abstract. This study aims to produce student worksheets based on the constructivism approach in a valid, practical, and effective Real Analysis course. This research method is research development with the Plomp model, which is divided into four phases. The research subjects were students of Mathematics Education at Lambung Mangkurat University who took Real Analysis courses in the short semester of 2016/2017 and the odd semester of 2017/2018. Validity is based on the results of the validator's assessment of student worksheets and research instruments. Practicality is based on observations of the implementation of student worksheets at all meetings. Effectiveness is based on observations, responses, and completeness of student learning outcomes. The first trial only met the validity and practicality criteria while the effectiveness criteria had not been met because student learning completeness did not meet the specified criteria and the results of the second trial had met valid criteria, practical, and effective. Based on these results, it can be concluded that the student worksheets are appropriate to be used in the real analysis learning process.

Keywords: student worksheets, constructivism, real analysis

1. Introduction

The development of education in tertiary institutions is greatly influenced by the teaching and learning process carried out by lecturers. Lecturers must do a variety of learning so that students are enthusiastic in following lectures and independent in learning. The independence of students in learning can be motivated by the use of teaching materials that are easily understood. Teaching material is material or content that must be mastered by students through learning activities in accordance with the desired curriculum, arranged systematically, both written and not so as to create an environment or atmosphere that allows students to learn and as a medium used by lecturers in carrying out teaching and learning activities in class. The absence of teaching materials causes students to become dominant listening and taking notes so that it becomes one of the factors causing learning that does not actively involve students [1]. There are many types of teaching materials used in learning, one of which is the use of worksheets.

Worksheets can be useful in terms of academic achievement, for example as a support for textbooks and can be used as an alternative learning strategy that is innovative, constructive, and student-centered so that the expected components on the worksheet can create an interactive, inspiring, motivating learning environment to participate actively [2]. The benefits of using worksheets in the junior and senior high school learning process include: influencing learning outcomes, building knowledge, influencing high-level thinking skills, increasing student competence, communication between students and teachers being effective, increasing conceptual understanding [3][4][5][6][7][8][9]. Even if applied in elementary school will also affect academic achievement, and activate students' cognition [10][11].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1 Worksheets given at tertiary institutions are student worksheets in the form of printed teaching materials, sheets of paper containing material, summaries, and implementation of learning tasks that students must do, both theoretical and practical, which refers to the competencies students must achieve. Some of the advantages of using worksheets in the learning process include students being able to learn according to their abilities so that students are expected to master the subject matter because they can repeat the material in the correct logical sequence [12]. Several studies have revealed the benefits of using worksheets in tertiary institutions, namely: making students more collaborative, improving combinational and correlational thinking skills [13][14][15][16].

The Real Analysis course is one of the compulsory semester V courses in the Mathematics Education Study Program of the Teaching and Education Faculty of Lambung Mangkurat University. Competencies that must be achieved after studying this course are students able to analyze problems, use mathematical logic (logical thinking competence) in solving problems, namely by using existing definitions/ theorems/ effects/ lemmas, and writing/ re-expressing solutions to those problems in the correct logic order.

However, based on the experience of researchers while teaching the course of Real Analysis, it is found that students are often constrained in conducting proof because students are not accustomed to solving problems in a logical order. Students use examples to prove a given problem. This is very contrary to the expectations of the objectives of learning real analysis. The reason is that students do not understand the material, as stated by [17] that students who are first studying real analysis usually do not have experience in understanding proof.

Researchers have tried various ways to overcome these obstacles. One of them is to give an example of how to prove a theorem and give an example of solving a problem using the definition / theorem / corollary but when given a different problem many students still have difficulty to solve it. The constraint was also stated by [18] that the types of difficulties in working on real number problems based on the dominant Watson error category occur in students' answers in the form of incorrect data types, incorrect procedures, conflict level responses, and hierarchical problems the skills. Besides teaching materials used are still using English so students are less motivated in constructing the material being studied because of language constraints and there are no learning activities or steps either individually or in groups to play an active role in constructing the concepts being learned themselves. One of the teaching materials expected to overcome this problem is a student worksheet.

The development of student worksheets results in students becoming active, as stated by [19] that High School student worksheets for Geography subjects so that students become active, interested, and not boring and [20][21] also developed worksheets for high school students in physics so that students become active. As for [22] developing student worksheets based on cognitive meta strategies for fluency, flexibility, and elaboration abilities. In addition, students also responded positively to the use of worksheets developed by [23] for fractional material and [24] to design digital worksheets for three-dimensional vector equality equations to improve students' visual and symbolic representations.

There are several development models that are used to develop worksheets, such as the 4D model [2][25][26][27][28], models Borg and Gall can improve students' high-level skills [29]. This research will use the Plomp model to develop student worksheets.

Worksheets have been developed at the tertiary level as conducted by [30] for formal definition material in function limits [31] developing worksheets for calculus courses so as to effectively improve student learning achievement. Therefore, the development of a good student worksheet will guide students to be active and creative in finding appropriate answers. The constructivism approach is a learning approach that emphasizes students constructing their own knowledge based on the experience they have [32] where the learning process begins with the occurrence of cognitive conflict that can only be overcome through self-knowledge and at the end of the learning process knowledge will be formed children through the experience of the results of interactions with their environment and the teacher no longer serves as the main source of learning because the constructivism approach makes learning centered on students [33].

Based on this, this study aims to develop a worksheet based on a valid, practical, and effective constructivism approach in the Real Analysis course in the Mathematics Education Study Program of the Teaching and Education Faculty of Lambung Mangkurat University.

2. Methods

The development of student worksheets in this study uses a modification of the General Model of Educational Problem Solving developed by [34] which consists of four phases, namely: 1) preliminary investigation; 2) design; 3) realization/ construction (realization/ construction), and 4) tests, evaluations, and revisions (test, evaluation, and revision).

Activities carried out in the initial investigation phase, namely: 1) analysis of learning problems; 2) analysis of student problems in learning; 3) material analysis; 4) task analysis, and 5) indicator specifications and learning objectives. Activities in the design phase, namely: 1) designing the organization of material into submatrices based on material characteristics and time allocation; 2) make a mapping of material and problem-solving activities; 3) the selection of instructional media, and 4) design student worksheets. The activities in the phase of realization/ construction, among others: 1) compile the way of presenting information; 2) arrange problem-solving activities, and 3) arrange stabilization activities. The final phase is expert validation and testing in real situations in the field.

The validity of the material is checked by two validators. Practicality is checked by two observers, and effectiveness is checked by students during field trials. The subjects of the trial were students of Mathematics Education at the Teaching and Education Faculty of Lambung Mangkurat University who programed Real Analysis courses in the 2016/2017 short semester and 2017/2018 odd semester. The material discussed on this student worksheet is the properties of algebra and the ordered properties of real numbers.

The research instruments used were validation sheets, observation sheets, student questionnaires, and tests. Data analysis in this study was a qualitative descriptive analysis used to analyze qualitative data in the form of notes, suggestions or comments and descriptive statistics to analyze quantitative data in the form of scores from the results of validation, observation, student response questionnaires, and learning achievement tests. Determination of the results of the validation and observation score adapts the steps developed [35] while the determination of the score of the student questionnaire responses and test results of learning to adapt the concepts developed [36].

Student worksheets are said to be valid if the average score of all aspects of validity is in the range of $2 \le \overline{V_a} \le 3$ and is said to be practical if based on observations, the implementation of the student worksheets developed in learning at all meetings meets high or easy criteria applied if the average score of all aspects of the practicality of student worksheets is in the range of $2 \le \overline{P} \le 3$. Student worksheets are said to be effective if fulfilled: 1) students achieve mastery learning; 2) student activities in learning at all meetings meet active or very active categories, and 3) positive student responses. Students are said to complete learning if they get a score of Seluruh 50. All classes are said to complete study if 85% of the students get a score of ≥ 50 .

3. Results and Discussion

3.1. Preliminary Investigation Phase Result

This phase has several activities, including the analysis of learning problems. This analysis aims to identify the problems that occur in lectures. Based on the experience of researchers as supervisors of real analysis courses often use lecture and practice methods. The method tends to emphasize the skills to do the questions, while the inculcation of the concept is only given in a short time. As a result students often make mistakes in working on problems. This error generally lies in the use of formulas, understanding or ability to digest mathematical language, and the application of concepts. Such conditions or learning trends can affect the low ability of students to solve mathematical problems. Lecturers have not optimally used problems as stimuli to explore students' abilities in solving problems.

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The next activity is the analysis of student problems in learning, found that there are still many students having difficulty solving problems about the properties of algebra in real numbers, especially related to proof of theorems / propositions. As a result, there are still students who have not reached the criteria for mastery learning as expected. These problems as stated by [18] that the factors that influence student difficulties are material that is difficult to understand and apply in problem-solving and personal factors that include poor learning patterns, supporting facilities, and lecturer factors.

Furthermore, material analysis in which the researcher identifies the concepts of algebraic properties of real numbers to be taught and compiles them systematically and links one concept to another that is relevant, thus forming a concept map for material algebraic properties on real numbers. The next activity is task analysis based on learning outcomes for the material properties of algebra in real numbers. Next, convert the objectives of problem analysis, material, and assignments into indicators and learning objectives or abilities that students must have. These capabilities include determining and proving the algebraic properties of real numbers.

3.1.1. Design Phase Result

The results of this phase are in the form of student worksheets that contain two main components, namely: 1) learning steps that contain student activity design in solving problems and 2) competency tests in the form of practice questions.

3.1.2. Realization Phase Result/ Construction

The design that was compiled in the next design phase was realized in order to obtain prototype I, namely student worksheets and research instruments. The prototype of the resulting student worksheet contains: 1) instructions for filling out the student worksheet; 2) construction learning steps, containing activities to solve problems in groups; and 3) competency test, an exercise in mastering the mastery of the material that has been learned that is done independently and in groups as can be seen in Figure 1 below.

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Figure 1. Student Worksheet Trial I

The student worksheet in Figure 1 is the worksheet used in the trial I where the effectiveness criteria have not been fulfilled so that the trial II continues, which results in prototype II as in Figure 2 below.



Figure 2. Student Worksheet Trial II

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The difference between the student worksheets in trials I and II lie in the design and sentence questions on the given problem and the symbols used. These changes are due to input from students as test subjects.

3.1.3. Test, Evaluation, and Revision Phase Results

The validation results are used to assess the validity of student worksheets and research instruments prior to conducting field trials. The results of the validation of student worksheets and research instruments are detailed in Table 1.

Assessment Aspect	Mean	Category
Content	2.8	Valid
Language, Writing, and Display	3	Valid
Benefits	2.7	Valid
Mean	2.8	Valid

Table 1. Student Worksheet Validation Results

Based on the results of the validator in Table 1, the average score of all aspects of the student worksheet is 2.8. According to the established validity criteria [35], the prototype of student worksheets can be said to be valid. The results of the validation of the research instrument can be seen in Table 2.

Instrument Assessment Aspect		Mean	Category		
Observation Shee	et of	LKM	Content	3	Valid
Implementation			Language and Writing	3	Valid
			Benefits	3	Valid
			Mean	3	Valid
Observation Sheet of	Students' A	Activity	Material	3	Valid
			Language and Writing	3	Valid
			Benefits	3	Valid
			Mean	3	Valid
			Material	3	Valid
Students' Questionnat	re Respons	se	Question Material	2.8	Valid
	_		Language and Writing	3	Valid
			Benefits	3	Valid
			Mean	2.93	Valid
Test		Question Material	3	Valid	
			Language and Writing	3	Valid
			Benefits	3	Valid
			Mean	3	Valid

Table 2. Instrument Validation Result

Based on the results of the validator validation in Table 2 obtained an average score on the instrument that meets according to the established validity criteria [35].

3.2. Field Test Results

This trial aims to assess the practicality and effectiveness of student worksheets. Trials were conducted twice, namely the short semester students of the 2016/2017 academic year and the odd semester students of the 2017/2018 academic year who took the Real Analysis course. Trial I conducted four meetings, while Trial II held three meetings.

3.2.1. Trial I Result

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The first trial took place from 7 July to 19 July 2017 in the Mathematics Education Study Program of the Teaching and Education Faculty of Lambung Mangkurat University. The number of students is 30 people. Face-to-face activities in this class take place three times with a duration of 150 minutes / meeting. This trial was observed by two observers who observed the implementation of student worksheets and student activities [35], as shown in Figure 3.



Figure 3. Observation Activity of One Observer

During learning, students are asked to work on worksheets in groups and answer all the questions on the worksheet even though there are groups who do not finish working on it because they have difficulty in connecting answers to questions before and after. After the discussion, one of the groups was asked to present the results of the group discussion in front of the class, as shown in Figure 4.



Figure 4. Presentation Activity

A summary of the results of the trial I can be seen in Table 3 below.

Effectiveness Indicator	Trial Result	Conclusion
LKM Implementation	High	Meet the specified criteria
Students' Activities	Active	Meet the specified criteria
Students' Response	Positive	Meet the specified criteria
Learning Accomplishment	Not accomplished	Do not meet the specified criteria

Based on Table 3, then in the trial I, the student worksheets that were developed did not meet the effectiveness criteria, so the student worksheets could not be said to be effective. This happens because the mastery learning has not been completed [36]. One reason is that there are still many students who

do not understand and distinguish the basic properties of real algebraic numbers such as closed and commutative properties. Like working on a student worksheet one of the groups in Figure 5.

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Figure 5. Example One of the Results of Work on Trial I Students

In problem 1 question c it appears that students have not been able to generalize the nature formed based on the previous question. Students have not been able to distinguish between closed and commutative traits, so the conclusions given are still not right. The conclusion given in problem 1 that the nature formed is commutative, and the same conclusion is given in problem 2 when the two problems are different. This means that the process of constructing the related knowledge in answering the problem given is still not right. One reason is that students are not accustomed to solving problems, finding something, and transforming complex information into another situation. Student worksheets only meet the criteria for validity and practicality (implementation). Therefore, it is necessary to revise student worksheets, which subsequently produce prototype II student worksheets. This prototype II worksheet will be used in trial II.

3.2.2. Trial II Results

Trial II took place from 11 September 2017 to 02 October 2017 in the Mathematics Education Study Program of the Teaching and Education Faculty of Lambung Mangkurat University. The number of students is 51 people. Like a trial, I, in trial II, was observed by two observers who observed the implementation of student worksheets and student activities. The summary of the results of trial II can be seen in the following Table 4.

Effectiveness Indicator	Trial Result	Conclusion
Effectiveness indicator	I Hai Kesult	Conclusion
LKM Implementation	High	Meet the specified criteria
Students' Activities	Active	Meet the specified criteria
Students' Response	Positive	Meet the specified criteria
Learning Accomplishment	Complete	Meet the requirement

Table 4.	Trial II	Analysis	Results
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Based on Table 4, the three indicators of effectiveness support the effectiveness of student worksheets. Therefore, in the second trial, this student worksheet that was developed met the effectiveness criteria, so that the student worksheet could be said to be effective. This can be seen as one of them in the operation of student worksheets; students can already answer the questions on student worksheets correctly. No more errors were found by students in working on student worksheets. Students can already distinguish between closed and commutative traits. As workmanship student worksheets one of the groups in Figure 6.

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Figure 6. Example One of the Work Out Results of Trial Students II

This means that student worksheets have met the criteria of validity, practicality (effectiveness) and effectiveness, hereinafter referred to as final student worksheets, namely student worksheets based on constructivism approach to the material of algebraic properties and sequential properties on valid, practical, real numbers and effective.

The resulting student worksheets complement the Plomp model development research conducted by [30] for formal definition material in function limits and [31] for calculus material.

Implementation of student worksheets in real analysis courses is expected to improve students' formal thinking skills in accordance with research [14] that the use of worksheets will improve combinational and relational thinking skills.

4. Conclusion

Based on the results of the development, it can be concluded that the student worksheet based on the constructivism approach developed on the material properties of algebra and sequential properties of real numbers fulfills valid, practical, and effective criteria. Based on the notes obtained during the field trial, it was found that there were strengths and weaknesses of the developed student worksheets. Strengths of student worksheets that have been compiled, namely: 1) student worksheets are arranged systematically for students to use in learning activities, so that students are easy to use; 2) student worksheets are written for the benefit of students so that the structure is adjusted to the characteristics of students; 3) student worksheets contain problems related to the material discussed and are accompanied by instructions and problem-solving steps to make it easier for students to solve these problems, and 4) student worksheets provide opportunities for students to practice doing exercises independently through questions exercise. The weaknesses of the student worksheets that have been compiled are the student worksheets that are only in accordance with the characteristics of the students of the Mathematics Education Study Program of the Teaching and Education Faculty of Lambung Mangkurat University.

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