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Developing the student worksheet with problem-solving approach to improve critical thinking skills and the concept understanding of physics

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Abstract: The study aimed to investigate the quality of the developed student worksheet with a problem-solving approach in line to the determined criteria and the improvement of students' critical thinking skills and the conceptual understanding of physics by implementing the student's worksheet. This study was a research and development study by applying the development model by Borg & Gall. The try out subjects of validation product were students of grades X and XI of MAN (Islamic High School) Yogyakarta III. The data collection techniques used validation sheets, observation sheets, evaluation sheets of student's worksheet, and tests. The product of this research was student's worksheet with a problem-solving approach on the topic of optical instruments for grade X of senior high school. The evaluation of student's worksheet by experts, teachers, peer reviewers, and students are at the best categories for learning, construct, and technical aspects. The gained standard score of students' conceptual understanding and students' critical thinking skills for grade X who learned through student's worksheet with a problem-solving approach, called treatment class, were higher than students who learned without student's worksheet with a problem-solving approach, called control class.

1. Introduction

Teachers as facilitators in the learning process play a strategic role in efforts to improve the quality of learning. Select the appropriate teaching material is a learning strategy that might perform by teachers to improve the quality of learning. A student worksheet is a form of teaching materials which might be used by teachers in the class. Nurichah, et al. (2012, pp.45-49) concluded that the student worksheet today contains theoretical questions to test the concepts or theories, but there are no questions that enable to train the students into critical thinking.

Physics is a subject in the brand of science that is identical to experimental activities or often referred to as practical activities. Based on the observations at MAN (Islamic High School) Yogyakarta II and MAN Yogyakarta III, the school has complete practicum equipment. However, the results of interviews with physics teachers in MAN Yogyakarta II, MAN Yogyakarta III, and SMAN (Senior High School) 9 Yogyakarta obtained information that not all physics subjects can be practiced or inserting the practical activities due to the time problems and preparation. Guidance and assessment of practical activities must be prepared by the teacher, such instruction and assessment of practicum. The statement is not in line with the curriculum2013, that physics as one subject in the family of science are expected to use a scientific approach that involves observing, asking, trying, reasoning, and communicating. The scientific approach aims to improve the understanding of students' concepts in the material (Sundaygara & Gaharin, 2017).

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LKS (Student's Worksheet) becomes important in practical activities because LKS directs the students to conduct practicum. Physics learning in each education unit is expected to provide the students with skills and abilities to solve the various physical problems in daily life. Therefore, students are taught how to solve the problems through physics learning. Research by Gok & Silay (2010, pp.7-21) concluded that physics learning with problem-solving strategies can improve student learning achievement. Problem-solving strategies are more effective in cooperative learning than conventional learning.

Research Ogunleye (2009, p.88) found out that aspects of student difficulties in solving the physics problems are caused the lack of students' understanding of the problems and the lack of students' mathematical skills. Lack of students' understanding of the problem is caused they do not understand the concepts of physics. Most of the students assumed that physics is a lesson full of mathematical formulas and must be memorized. Students do not understand the concepts in problems related to physics. The statement is supported by the results of observations made by the researcher at MAN Yogyakarta III, which are most of the physics questions contain mathematical formulas. The fact supports the opinion that physics is identical to mathematical questions. Furthermore, the students' physics concepts are weak to solve the question. There are still many students who identify the questions based on the keywords in the questions. The result of observation becomes the material for researchers and concluded that students' concepts understanding in physics is still weak.

Concept understanding is a competency must be possessed through learning. Gorman (1974, p. 322) concludes; problem-solving is an approach to improve the critical thinking skills. Learning using a problem-solving approach can influence the students' critical thinking skills. Today, critical thinking skills are very necessary especially in the development of science and technology, because the rapid development has impacts that create problems for humans and the environment. Critical thinking skills are explicitly mentioned in the curriculum 2013 as competencies that must be possessed by students.

In fact, learning activities at MAN Yogyakarta III on the optical instrument material have carried out practical activities. But, the practicum is limited to the use of mirrors and lenses as conceptual reinforcement of the students' knowledge in junior high school. The material about the application of mirrors and lenses on optical devices has not conducted with practical activities because the teacher assumed the experiments must use the application of optical devices in real terms. Practical activities at MAN Yogyakarta III aim to prove the concepts, and the worksheets already contain the work steps in detail in accordance with the procedure on the practicum. Meanwhile, the detailed work steps in the worksheet do not facilitate students to make critical thinking in solving the problems.

The article tries to make a teaching material to facilitate the student of Senior high school / Islamic High School to always use problem-solving strategies in solving the physics problems, especially in optical instrument material. The teaching material is in the form of Worksheet to guide the students' practical activities on the subject of optical devices.

The study aimed to determine the quality of student worksheets with a problem-solving approach that was developed in accordance with the specified criteria and improvement of students' critical thinking skills and understanding of physics concepts by implementing the worksheet.

The problem-solving approach in learning activities is an effort to find a way out of the problems through investigation activities (Hafizah, Misbah, & Annur 2018). The syntax of the problem-solving approach in physics according to Heller & Heller (2010, p. 41) is the understanding the problem, describing the problem, planning a solution, implementing a completion plan, and evaluating the results. The investigation activities carried out in accordance with the specified indicators, and then the developed worksheet has not contained the detailed work steps. Students determine their own work steps with the help of questions included in the LKS. The efforts of students to solve the problems independently are the example of the use of problem-solving strategies.

Critical thinking skills are higher-order thinking skills (Aji, Bernadino, & Hudha, 2017) (Prani, Parno, & Hidayat, 2018). Here, the students think evaluatively to measure further actions to solve the problems. Critical thinking skills are measured using a written test. Indicators of critical thinking skills are, formulating the questions or arguments, comparing two arguments, clarifying an argument, detailing the use of appropriate procedures, collecting correct evidence, diagnosing a hypothesis, combining informations to make decisions, concluding observations, comparing the strategy used to define an argument, predict the reasons for decision making, and determine an action.

Gaigher (2006) concluded that problem-solving might turn into practice because the students' skills in problems solving also improved. Problem-solving can also facilitate language understanding and physics concepts. Understanding the physics concept is the ability to formulate the meaning of the learning message and communicate it in oral, written and graphical forms about the physics concepts. Understanding the students' concepts is measured using a written test. The measuring indicators for understanding concepts are, explaining the concept, giving examples of a concept, explaining inter-concept linkages, explaining a whole frame of mind, explaining a concept from a picture or graph, classifying a concept, estimating or making a hypothesis from a concept, draw conclusions related to a concept, and set a scientific step based on the conclusions.

2. Methods

The research was research and development. Borg & Gall (1983, p.775) explained ten steps in Research and Development (R & D). But, this study carried out the step until the seventh stage. This development research was conducted in the even semester of the 2013/2014 academic year. The study conducted at MAN Yogyakarta III.

The trial subjects were students of class X and XI at MAN Yogyakarta. Class X students played as small group trials and preliminary field trials, because, the material of worksheet was for class X. The XI class students played as the one to one test trial for the readability test. Class XI considered having a good understanding of understanding the material in the developed worksheet and also, might estimate the difficulties toward the developed worksheet.

The developmental procedures divided into seven stages; (1) the stage of collecting information consists of literature studies and field surveys. The literary study aims to collect information related to the product. Field surveys aim to obtain information about the conditions and facts of physics learning in the field. (2) The stage of planning is an analysis to determine the contents. (3) The stage of developing the draft. The draft is tested first by the expert whether the product is appropriate to use or not as alternative teaching material. Not only the assessment by experts, but the assessment also carried out by the teacher and colleagues. (4) Initial field trial stage. The preliminary trials carried out twice; one to one testing and small group trials. The one to one testing relates to the readability of the worksheet. Small group trials relate to the implementation of worksheets. (5) The stage of revision toward the main product carried out based on the results of the students' assessment of the initial trial. (6) The main field trial stage. The trial aims to find out the validity and effectiveness of worksheet with a problem-solving approach. There were two groups in the stage; a group of the subject of the product trial and a group of the control group. The obtained data and inputs used as material for revision and improvement to improve the product. (7) The revision stage of the operational product carried out based on input data result of the main field trial to improve the product.

The data collection instrument used validation sheet, observation sheet, worksheet assessment sheet, and written tests. The validation sheet used to test the developed worksheet. Validation sheets are given to experts, teachers, and colleagues. The observation sheet used to record the important events and students' responses during the product trial process. The worksheet assessment sheet used to determine the product quality evaluated by the subjects. The worksheet assessment sheet is given to students in one

to one testing, small group trials, and initial field trials. Written tests used to obtain data on students' critical thinking skills and understanding of physics concepts.

Analysis of the instrument validity used the Rasch model with the help of the ministep program. The criteria for determination the instruments by Bambang Sumintono and Wahyu Widhiarso (2013, p.111) were (a) the score of Outfit Mean Square (MNSQ): 0.5 <MNSQ <1.5. (b) The score of Outfit Z-Standard (ZSTD): -2.0 <ZSTD <+2.0 (c) score of Point Measure Correlation (Pt Mean Corr): 0.4 <Pt Measure Corr <0.85.

Overall of instrument reliability score is determined on alphacronbach score. Bambang sumintono and Wahyu Widhiarso (2013, p. 109) stated the criteria of alphacronbach score: <0.5: very poor; 0.5–0.6: poor; 0.6–0.7: moderate; 0.7–0.8: good; > 0.8: excellent. Analysis of the product evaluations used the following formula.

$$\bar{x} = \frac{\Sigma X}{n}$$

Where:

$\bar{x}$ is the average score for each sub aspect of quality; n is the number of assessors; ΣX is the number of scores for each sub aspect of quality.

Data of comments, suggestions, and results of product trial observations were analyzed on descriptive qualitative. Data on assessment results were converted to qualitative data using a four-scale as presented in Table 1

Tabel 1. Converting Quantitative Data to Qualitative Data with a Four-Scale (Ministry of National Education, 2010, p.60)

Range of Score	Criteria
$Mi + 1,5SDi \leq \overline{M} \leq Mi + 3,0SDi$	Excellent
$Mi + 0SDi \leq \overline{M} < Mi + 1,5SDi$	Good
$Mi - 1,5SDi \leq \overline{M} < Mi + 0SDi$	Moderate
$Mi - 3,0SDi \leq \overline{M} < Mi - 1,5SDi$	Poor

Where

Mean ideal (Mi) = ½ (score of maximal ideal + score of minimal ideal)

Standard Deviation Ideal (SDi) = 1/6 (score of maximal ideal – score of minimal ideal)

Mean ($\overline{M}$) = average score

The observation sheet used to observe the implementation of learning activities. The observation sheet is rated according to the descriptor during the learning activity. The percentage scale to determine the implementation of learning used the following formula:

$$\% = \frac{\text{implemented descriptor}}{\text{number of descriptor}} \times 100\%$$

The score of the written test used to test the hypothesis aiming to find out does learning using a worksheet with problem-solving approaches more effective compared to conventional learning in critical thinking skills and understanding of physics concepts.

The formulations of the hypothesis are:

Ho: $\mu 1 = \mu 2$: critical thinking skills and understanding of physics concepts of students who learned using a worksheet with problem-solving approaches and critical thinking skills are same or equal with the

understanding of physics concepts of students who did not learn using a worksheet with problem-solving approaches

Hi: $\mu 1 \neq \mu 2$: critical thinking skills and understanding of physics concepts of students who learned using a worksheet with problem-solving approaches and critical thinking skills are not same or equal with the understanding of physics concepts of students who did not learn using a worksheet with problem-solving approaches

$\mu 1$: the average score of critical thinking skills and understanding of physics concepts of class population which learned using worksheet with problem solving approach (treatment class)

$\mu 2$: the average score of critical thinking skills and understanding of physics concepts of class population which learned using worksheet with problem solving approach (control class)

Based on the tested variables; independent variables (worksheet with problem-solving approach) and dependent variables (critical thinking skills and understanding of physics concepts), multivariate variance analysis (MANOVA) using the SPSS 16.0 program used to test this hypothesis.

The differences between tests of critical thinking skills and understanding of physics concepts on learning using worksheets and conventional learning investigated through the following testing stages.

2.1. Normality test

Normality test aims to find out the normal distribution data of a population. Data is normally distributed at a significance level of 5% if the probability of calculation is higher than 0.05. Data normality test performed using the Kolmogorov-Smirnov statistical test (Kolmogronov-Smirnov Test) in the SPSS 16.0 computer program.

2.2. Homogeneity Test

The homogeneity test aims to find out the homogeneity of a sample. The research sample is homogeneous at a significance level of 5% if the probability of calculation is higher than 0.05. The data homogeneity test performed using the homogeneity variance statistical test in the SPSS 16.0 computer program.

2.3. Hypothesis Test

Hypothesis test performs using multivariate tests. Multivariate tests carried out on the data of the standard gain score of students. The testing criteria are H0 rejected at a significance level of 5% if the probability value is smaller than 0.05. Hypothesis testing used the SPSS 16.0 computer program.

Data for hypothesis test was standard gain score. The standard gain calculation refers to the following equation:

$$Standard\ Gain = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

(Hake, 2002, p.3)

3. Results and Discussions

The products of the study were student worksheets (LKS) with problem-solving approaches on the material of optical devices. The developed products used to guide students in performing the experimental activities especially on the material of optical devices. The product characteristics have formats: (a) title; (b) objective; (c) problems; (d) accompaniment questions; (e) hypothesis; (f) experimental design; (g) work procedures; (h) experimental data; (i) data analysis; (j) conclusions; and (k) competency test.

The products were assessed by experts, teachers, peers, students in the preliminary trials, and students in the main field trials. Product assessment includes assessment aspect of didactic, construction,

and technical. The assessment results are converted into the formula in Table 1. So, it obtained the assessment results in certain criteria. The didactic aspects of the assessment result are presented in Figure 1.

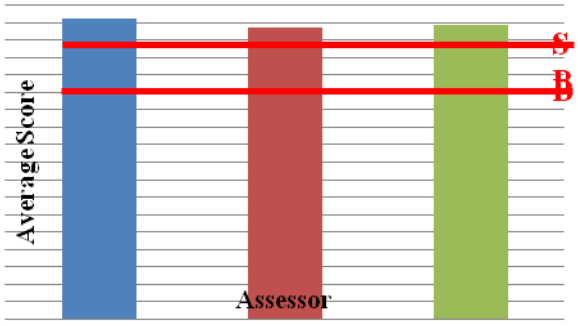

Figure 1. Diagram of didactic aspects of the assessment result

Assessment of didactic aspects is given to experts, teachers, and colleagues. Students did not include in assessing didactic aspects because students are assumed to not understand this aspect. Based on Figure 1, the assessment of the didactic aspects is in excellent criteria. This finding showed the universal characteristic of the worksheet, that is, it might use well for not too smart or smart students. Assessment in the construction aspect is presented in Figure 2.

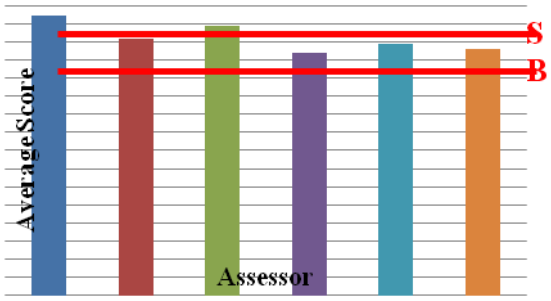

Figure 2. Diagram of construction aspects of the assessment result

All the criteria of the assessment results on the construction aspects were in excellent criteria. This finding showed that language usage, sentence structure, vocabulary, level of difficulty, and clarity in the product are fulfilled well. Assessment in the technical aspect is presented in Figure 3.

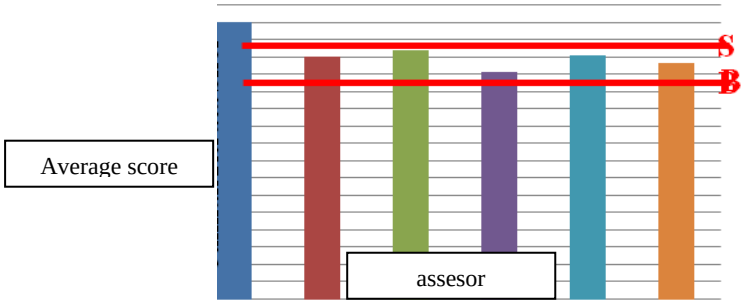

Figure 3. Diagram of technical aspects of the assessment result

All the criteria of the assessment results on the technical aspects were in excellent criteria. This finding showed that the technical aspects such wiriting, image, and display of the product are well fulfilled well.

There are data on the implementation of learning activities using developed worksheets. In the field trials, there were four assessments of the feasibility of the product according to each sub-material. The results of observations on the implementation of learning activities using worksheets with a problem-solving approach are presented in Figure 4.

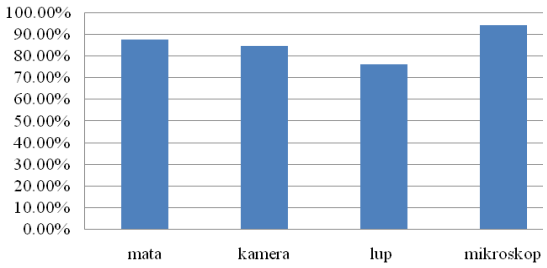

Figure 4. Diagram of the Implementation of worksheet

Based on Figure 4, the percentage of the implementation of the worksheet using a problem-solving approach is more than 75% for each sub-material. This finding showed that the learning activities using a developed product can be performed well. The magnifying glass sub-material is a sub-material on the worksheet that has the lowest percentage of implementation because the student during observation using lup, they must observe alternately. Then, it needed a quite long time for students to make observations. In fact, it impacts on not all students in a group making observations.

The effectiveness aspect is assessed based on two aspects; understanding concepts and critical thinking skills of students. Aspects of understanding the concepts and critical thinking skills of students measured based on the increasing score of pretest and posttest data both treatment class and control class.

The pretest is given at the beginning of the learning activity aiming to find out the students' initial cognitive abilities. And, the posttest is given at the end of learning. Achievement of students' competence is assessed from the students achieving to KKM scores (Minimum Completion Criteria). The KKM set by the school is 75. Here, the students achieve learning completeness when the score is more or equal to the specified KKM score. The percentage of student learning completeness both in critical thinking skills and understanding of physics concepts is presented in Figure 5.

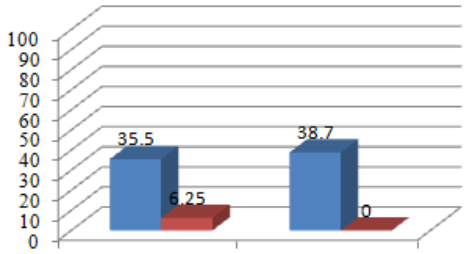

Figure 5. Diagram of students' learning completeness

In Figure 5, the completeness of learning in the test of conceptual understanding and critical thinking skills does not be higher than 50% both treatment class and control class. The low number of students' mastery might be analyzed because the completeness criteria set are quite high and students are not

familiar with conceptual questions and critical thinking that they have long characteristics sentence. Most students complain to question with a long sentence.

The standard gain score used to test the hypothesis of each student. The normality test used to determine the statistical test which was a parametric or nonparametric statistical test. The Result of Normality test of Standard Gain Score is presented in Table 2.

Tabel 2. Result of Normality test of Standard Gain Score

Data	Class	Probability (sig.)	Where
Concept Understanding	Treatment	0,200	Normal
	Control	0,200	Normal
Critical Thinking Skills	Treatment	0,200	Normal
	Control	0,200	Normal

Based on the data in Table 2, the standard gain of the conceptual understanding test and the critical thinking skills test are normally distributed both the treatment class and the control class. Based on these data, parametric statistical test are used in a statistical test.

There were two dependent variables; understanding the concepts and critical thinking skills with metric data. And independent variables were the use of worksheet with a problem-solving approach with nonmetric data. Therefore, the multivariate ANOVA test (MANOVA) used to test the hypothesis.

The variance test must be fulfilled before conducting the MANOVA test. The variance test on MANOVA carried out in two stages; variance test on each dependent variable and variance test on population. The result of the variance test for each dependent variable is presented in Table 3.

Tabel 3. Result of variance test on each dependen variable

	F	df1	df2	Sig.
Concept Understanding	0,020	1	61	0,889
Critical Thinking Skills	2,996	1	61	0,089

Table 3 showed the two significance values of the variable are higher than 0.05. So, the variance of each variable is homogeneous. This finding showed that the first assumption of MANOVA is fulfilled. Then, the second assumption of the overall population variance test presented in Table 4.

Tabel 4. Result of variance test of population

Box's M	4,175
F	1,342
df1	3
df2	6,931E5
Sig.	0,259

Table 4 showed the Box's M score is 4.175 with a significance score of 0.259. Based on the significance score is higher than 0.05, concluded that the variance matrix of understanding the concepts and critical thinking skills in groups is homogenous. This finding showed that the second assumption of MANOVA is fulfilled. In short, the MANOVA analysis can be continued.

Table 5 is the results of the MANOVA test which aimed to find out the effect of worksheet on understanding the concepts and critical thinking skills collectively. Meanwhile, table 6 is the effect of worksheet on understanding the concepts and critical thinking skills separately.

Tabel 5. The result of MANOVA Test aimed to find out the effect of worksheet on understanding the concepts and critical thinking skills collectively

	Effect	Value	Sig.
Class	Pillai's Trace	0,654	0,000
	Wilks' Lambda	0,346	0,000
	Hotelling's Trace	1,888	0,000
	Roy's Largest Root	1,888	0,000

Tabel 6. The result of MANOVA Test aimed to find out the effect of worksheet on understanding the concepts and critical thinking skills separately

Source	Dependent	Type III Sum of Squares	Mean Square	F	Sig.
Class	Understanding the Concept	1,572	1,572	57,474	0,000
	Critical thinking skills	2,002	2,002	82,355	0,000

Based on Table 5, the results of four - MANOVA statistical tests obtained a significance value of 0,000. Therefore, the results of the MANOVA test aimed to find out the combined effect might draw conclusion that there are differences in understanding the concepts and critical thinking skills between treatment classes and control classes.

Table 6 used to find out the difference in test results for each dependent variable. Based on the data in Table 6, concluded that there are differences in the conceptual understanding between treatment classes and the control class. And, there are differences in critical thinking skills between treatment classes and control classes.

The average score of the standard gain in the treatment class and the control class used to find out the differences the results of the concept understanding tests and critical thinking skills. The average score of standard gain is presented in Table 7.

Tabel 7. Average score of Standard Gain

No.	Description	Treatment Class	Control Class
1	Average score of standard gain of understanding the concept test	0,66	0,35
2	Average score of of standard gain of critical thinking skill	0,62	0,26

Based on Table 7, summarized that improvement of understanding the concept in the treatment class is better than the control class. Improvement of critical thinking skills in the treatment class is better than the control class.

4. Conclusion

The student worksheet with a problem-solving approach on optical instrument material was valid in the category of "excellent." In sum, this product is appropriate to use as a learning resource. The product on optical instrument material reached the practical criteria, seen from the implementation of the worksheet in the main field trial. The lenses used in the experiment have adapted to the lenses available on the market. The product statistically can improve the critical thinking skills and understanding of physics concepts.

The particular article suggests recommendations. The student worksheet with a problem-solving approach on the material of optical instruments has tested for validity, practicality, and effectiveness. So, this article suggested to teachers to use this product as alternative activity in class X, especially physics learning on optical instrument material. The use of student worksheet with problem-solving approach on optical instrument material developed by researchers can be added with simulations, such previously used

by researchers to emphasize the understanding the concept because of the limitations of the tools available on the market. The development of worksheets with a problem-solving approach in the eye sub-material has an example of using lenses. Therefore, it needs further explanation to students to avoid any misperceptions.

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