Developing Problem-Based worksheet to improve students’ critical thinking skills and learning outcomes in the concept of chemical bonding

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Abstract. This study aims at developing worksheet on problem-based chemical bonding material to determine quality, critical thinking ability and learning outcomes on the worksheet. Research and development (R & D) was used in this study. The population in this study were all students at X science class at senior high school Banda Aceh, Indonesia in 2018/2019 academic year. Sample selection in this study was done using random sampling with students at X science class and X science class. Data were analyzed using N-Gain test and t-test after the test showed that problem-based worksheet can improve student’s critical thinking skill (CTS). This can be seen from the N-Gain value from each indicator with the high category; and it was also strengthened with the Z test on each t-test indicator that showed the value of \( t_{\text{test}} = 5.08 \) and \( t_{\text{table}} = 1.68 \). It can be concluded that there are differences of the increase students’ learning outcomes between experimental class and control class through the development of problem-based worksheet on chemical bonding material.

1. Introduction
The achievement of the implementation of learning objectives can be seen from students’ learning outcomes. The results in terms of this context referred to the ones of chemistry learning that achieve learning completeness. The completeness of a material is the form of success of a student that deals with chemistry learning outcomes with minimum completeness criteria set by a school institution [1, 2]. Students who possess good CTS usually have better thinking skills. Learning outcomes are a form of change that arises from behavior of each individual which consists of three domains namely cognitive, affective and psychomotor [3]. Students who have optimal learning outcomes are usually those who have good CTS. Thus, they are able to investigate problems accordance with their extent [4,5].

The low students’ learning outcomes in chemical material can be seen from the acquisition of national examination scores obtained during the last three years. This showed the decline in value...
from 2014/2015 to 2016/2017 with successive percentages were 69.47, 59.60 and 53.39. Furthermore, the national examination scores in 2015/2016 and in 2016/2017 academic year on chemical bonding material was one of chemical materials with the lowest average score with the average score was around 65.23 and 12.36.

The ability of students analyzing a material well makes learning outcomes optimal. It can be achieved by honing student’s thinking skills so that they can construct problems independently [6]. Student’s CTS can be honed by making decisions, solving problems, providing evidence and making conclusions [7, 8]. This can be applied by using a learning tool in the form of student worksheets. Worksheet that is used in schools has not been made by the teacher; but he/she buys it from publishers who ready use it without planning, preparation and development by the teacher. This matter causes students’ learning outcomes become low and lacks skills of students in critical thinking. The worksheet should be able to help students to carry out learning activities and directly students can analyze and find alternative ways independently without the dependence on the teacher [9, 10].

Based on the preliminary observations made at senior high school Banda Aceh, there were several obstacles in learning process such as teaching and learning process which was still focused on the teacher (teacher-centered). This fact can be seen from students who more often recorded what the teacher gave. This can cause students become inactive and less enthusiastic in doing the tasks given. In addition, from the results of interviews with teachers found that there was still lack of teaching materials in the form of worksheet which can stimulate student’s thinking skills. As a result, students did not understand the problems faced and it caused student’s learning outcomes became low.

One solution that can be done is to develop learning tool that can help students improve their student’s CTS especially in chemistry learning. Problem-based worksheet is an appropriate innovation for the material because students can find their own way about concepts of chemical bonding material and can train their critical thinking skills so that they can improve their learning outcomes [11,12].

The development of problem-based worksheet was adopted from a study of development of problem-based worksheet in physics learning. However, because the worksheet in physics material was conducted, therefore, the authors wanted to develop problem-based worksheet in chemistry learning to improve students’ CTS and learning outcomes [13, 14].

Several studies on the development of problem-based worksheet had been successfully carried out and had a good impact on the learning process. This was accordance with the research by [15] that problem-based worksheet influenced the improvement of CTS with N-gain average of 65.7. It means that problem-based worksheet affects the increase of students’ CTS.

Problem-based worksheet can also help students solve problems [16]. It is known from an increase on student learning outcomes is about 75%. Through problem-based learning students can understand the problem specifically, open their thoughts on the arguments conveyed by others, filter out any information obtained before making a decision and link problems well in each learning process [17, 18].

Regarding the above problems in relation to the lack of use of teaching materials and the low results obtained by students in national examinations in recent years, it is necessary to conduct Problem-Based Development worksheet research in improving students’ CTS and learning outcomes in chemical bonding material at senior high school Banda Aceh.

2. Method

This research method used research and development (R & D) with the ADDIE model. The research design was in the form of pretest and posttest control group. The population in this study were all students of X science class at senior high school Banda Aceh in 2018/2019 academic year. All science departments have 152 student that contain 5 classes. The selection of samples using random sampling techniques from the results of sampling obtained from 31 students in experimental class (X science2 class) and 30 students in control class (X science3 class). Data were analyzed using percentages for test validity, N-gain and t-test for learning outcomes.
3. Result And Discussion
This research had been carried out to collect the needed data. These data were then analyzed to determine the quality of the worksheet products developed, the increase of students’ CTS and learning outcomes of two classes whether there were differences in problem-based worksheet.

3.1 Development of Problem Based Worksheet Product
The development of worksheet for the problem-based chemical bond material used the ADDIE model which stands for analysis, design, development, implementation and evaluation.

3.1.1 Analysis, The Analysis phase was carried out through a field study that aimed to dig up information about learning in schools, and also discover information regarding the availability of learning resources found in schools. The school chosen in this study was senior high school Banda Aceh. The analysis process was done by interviewing teachers and students who were in that school. In addition, the results of interview with chemistry teachers gathered that there was still lack of learning tool that can construct students in solving problems during the learning process and can improve student's CTS. This thing brought an impact on student learning outcomes.

3.1.2 Design, The process of design stage was done by designing the worksheet. The designed worksheet was problem based worksheet.

3.1.3 Development, The development begun with a validation process. The assessment of quality of worksheet based on the engineering content of the development of worksheet, the design of worksheet development, the feasibility of contents of worksheet, the presentation of worksheet, the illustration and grammar of worksheet.

3.1.4 Implementation, At this stage the application process of worksheets undertaken by means of the validation process. The implementation of this worksheet was conducted at senior high school Banda Aceh with the aim of hypothesis testing whether there was an increase of students’ CTS and some differences on learning outcomes between experimental class and control class.

This stage was employed by implementing the developed worksheet that had been validated and revised. The worksheet was implemented in senior high school Banda Aceh aimed to look at whether there was an increase on learning outcomes between two classes that used problem-based worksheet (experimental class) and without the use of problem-based worksheet (control class). The experimental class was the science2 class; while the control class was science1. This stage begun with the implementation process in the form of giving pre-test to find out the students’ beginning ability related to chemistry material, and at the end of the learning was given post-test to find out whether the student’s abilities increased or vice versa. The pre-test and post-test were made in a reasoned multiple choice form which comprised to 20 questions.

3.1.5 Evaluation, Evaluation is the final stage; the stage of evaluation was conducted in the form of students’ CTS assessment and learning outcomes for both experimental class and control class through the implementation of problem-based of worksheet.

3.2 Critical Thinking Skills
The indicators used to measure critical thinking skill in this research with the CTS indicators according to (14) are: (1) indicators analyzing arguments, (2) indicators making induction and making induction, (3) indicators making induction and considering induction, (4) indicators determine an action, (5) indicators make and consider the value of the decision. The increase of students’ CTS was calculated based on pretest and posttest that had been given in learning process after following the learning process which was reviewed based on these indicators. Based on the average N-Gain value of students’ CTS for each CTS indicator can be seen on chart 1.
Based on chart 1 the percentage of average value of N-gain for each CTS indicator in experimental class was in the high category; while in control class was in the medium category. The highest CTS indicator in experimental class dealt with making and considering of the results of induction; whereas, for control class was related to making and considering the results of decision.

Problem-based worksheet designed so that students did not have difficulty in analyzing problems. Besides, students were expected to be able to answer questions that involved drawing conclusions correctly accordance with the ongoing learning. Problem-based worksheet was able to help students construct the answers for questions and wrap up conclusions from problems [19, 20].

The average increase on the five students’ CTS indicators revealed that problem-based worksheet can improve student’s CTS according to the indicators developed by Ennis [21]. It means that problem-based learning can improve critical thinking skills. This was in lined with the research by [22] problem-based learning that had a positive impact on improving students’ learning outcomes.

### 3.3 Student’s Learning Outcomes

The assessment of participants' learning outcomes in the chemical bond material in this study was obtained from the values of pre-test, post-test, and N-gain with the aim of knowing students’ learning outcomes between experimental class and control class in the secondary school. The results attained that students’ pre-test score on chemical bonding material was different between two classes in which post-test result increased. Furtermore, there was a better improvement in experimental class compared to control class. This can be seen from the N-gain value from both classes which the valeu for experimental class was 82.92 that included into the high category, while the value for control class was 43.39 that entailed into the low category. The learning outcomes here were cognitive changes from the intellectuality of learners after the problem-based learning model applied [23].

The learning outcomes obtained from this study analyzed to test the hypothesis about learning of the use of worksheet problem-based chemical bond material in experimental class compared to control class without using the worksheet. Testing of hypothesis was done through statistical tests using SPSS 20 software. The result of analysis of hypothesis testing was carried out on the N-Gain value data as presented in Table 1.
The results of data analysis from testing the value of N-Gain which tested the average of difference in Table 1 obtained t-count. This showed that there were differences on students’ learning outcomes between experimental class and control class after learning activities carried out in experimental class and control class. It means the N-gain value of experimental class was higher than the control class. In other words, there were significant differences between experimental class and control class which the use of problem-based worksheet can improve students’ learning outcomes. The improvement of learning outcomes in experimental class was marked by the value of each student post-test which was very well identified for each reason provided with the right reasons from the answers chosen.

The increase of students’ learning outcomes between experimental class and control class were also caused by learning activities that paid attention to the stages of problem-based learning as stated in the problem-based worksheet starting from the following steps (1) Doing student orientation toward the problem, (2) Guiding individual and group investigations (3) Guiding individual or group investigations, and (4) Developing and presenting works. These stages require students to search and analyze problems independently and find solutions for each problem obtained by students so that learning outcomes can be increased.

Students at this stage were trained to find out and analyze each problem from the root point and resolve independently through the hypotheses found in the learning process. Problem-based learning trains student’s skills in solving problems and finding answers independently [24, 25]. Through problem-based learning students are able to construct problems and build basic skills because when learning takes place students are guided to maintain arguments by giving reasons [26, 27].

Learning to use this problem-based worksheet can increase the activeness of student’s creativity according with what was stated by [28], that problem-based learning can improve students’ creativity. This can be seen from the increase in value of 36.50% and N-gain 52.52 with the average criteria. Besides, according to [29], problem-based learning can increase students’ creativity.

Learning with worksheet is also very useful for students because it can support their learning actively and independently and can also improve students’ learning outcomes. Therefore, the use of problem-based worksheet can enhance students’ learning outcomes [30, 31].

Worksheet on problem-based chemical bonding material used had brought a positive impact that can increase students’ CTS and learning outcomes in experimental class because the score that the students got was higher than the ones who were control class. Thus, the development of problem-based worksheet can be a solution toward the problems found in schools especially to improve students’ CTS and learning outcomes on chemical bonding material that was studied to solve problems found in the material. The development of worksheet can make students more creative and possess CTS.

### Table 1. Results of t-test analysis of N-Gain data value

| Class   | N-gain Value | t test | Meaning       |
|---------|--------------|--------|---------------|
| Experiment | 70.09 | 5.08  | 1.68  | differences |
| Control     | 46.76 | 5.90  |        |         |

4 Conclusion

Based on the results of data analysis and the discussion can be concluded that (1) The feasibility of worksheet on problem-based chemical bond material based on validation by chemistry experts and teachers obtained the average scores were 91.69 and 86.91% categorized as very feasible. (2) Problem-based worksheet can improve students’ critical thinking skill students. This can be seen from
the N-Gain value of each indicator in the high category and strengthened by the Z test on each indicator that showed the effect of using problem-based worksheet on the improvement of CTS indicators. (3) Problem-based worksheet can improve students’ learning outcomes which can be known from the result of hypothesis testing that indicated some differences between experimental class and control class in relation to the influential problems that provide meaningful learning in improving students’ learning outcomes.

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