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Enhancing Critical Thinking Skills of Students Related to Temperature and Heat Topics Through Problem Solving-Laboratory Model

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Abstract

This study aims to determine the implementation of the learning problem-solving laboratory model and improvement of critical thinking skills of students on temperature and heat topic. The method used in this research was pre-experiment, with one-group pretest-posttest design. The population of this study was class X SMA Muhammadiyah 1 Garut. The sample was selected by random sampling technique, with a sample of one class X-2, amounting to 30 people. The implementation of problem-solving laboratory model learning was observed by observers with observation sheets and improvement of students' critical thinking skills measured by essay tests. The results showed that the average implementation of problem-solving laboratory model learning for teacher activities was 84%, and student activities at 80% were both categorized well. There was an increase in the critical thinking skills of students shown by the average of the normalized gain value of 0.64 include the medium category. Thus, the problem-solving laboratory model learning can be used as an alternative in improving students' critical thinking skills on the topic of temperature and heat.

Keywords: problem-solving laboratory, critical thinking skills, temperature and heat

INTRODUCTION

Higher education has an essential role in the 4.0 industrial revolution. Especially universities that produce prospective educators are expected to produce graduates who have the expertise that supports them to become successful individuals in the world of work and social life (Sapriadil et al. 2019; Hunaidah et al. 2018). Education stakeholders must be able to anticipate the progress of science and technology so that they can prepare future generations who are ready and adaptive to respond to all demands (Fuad et al. 2017). Teachers, in order to improve and develop students' higher order thinking skills, utilize and use different strategies (Abosalem 2016). Students' skills in studying and deepening knowledge, critical thinking, choosing the information that is considered reliable, analyzing it and synthesizing it with prior knowledge so that their knowledge is more reliable and scientific needs to be trained and developed (Kementerian Pendidikan dan Kebudayaan 2016).

A central goal of science education is to help students develop their higher order thinking skills to enable them to face the challenges of daily life, through adopting activities that encourage students to use higher order thinking skills (Saido 2015). Rusli (2013) explaining physics learning for the 21st century must have awareness, insight, depth, and ethics. Awareness of the importance of physics will be supported if learning takes students to explore a fairly wide area in physics. One of the roles of physics is to solve problems faced in life using methods based on scientific considerations. The role of physics to solve problems faced by humans, especially in considering understanding the benefits and impacts of technological developments for life requires high-level skills, one of which is critical thinking skills.

Critical thinking skills are needed in human life, which is always faced with problems so that a logical decision is needed to solve the problem (Purwanto, Nugroho & Wiyanto 2012). The development of critical thinking has been universally adopted as an important goal of higher education. Critical thinking skills are a component of the curriculum that must be trained and developed for students in science education, especially physics (Zhang 2018; Sastrika, Sadia & Muderawan 2013). Critical thinking skills are needed by students to consider knowledge, analyze, and evaluate information, also make their own decisions related to their academic success (Nold 2017; Birgili 2015).

The preliminary studies conducted at SMA Muhammadiyah 1 Garut through interviews with teachers and students. The observation of learning conducted by teachers in the classroom. The preliminary studies results show that the learning that occurs is still teacher-centered so that in its implementation, it has not been able to train aspects of students' thinking skills. Teachers more often explain their concept and then give practice questions to students without train skills that can motivate students to understand better what they are learning. Besides, laboratory activities as a characteristic of physics learning are rarely done. The laboratory activities are one method that can train students' higher order thinking skills (Lisdiani et al. 2019; Safitri et al. 2019; Malik et al. 2019a).

The observation was done to see how critical thinking skills of students are trained and developed during the learning process. The results of the observations indicate that in learning the teacher delivers material with blackboard media. Then ask students to ask questions that are not understood and then continue with the practice of questions. The previous teacher did not allow students to explore their initial concepts and did not allow students to actively discover the concepts they were learning. Students who actively ask during learning are only a few people. When at the end of the lesson the teacher concludes the material that has been learned while the students only take notes. This is following the results of interviews with teachers and students that have previously been carried out. Teaching and learning activities can be done effectively and efficiently if the learning materials designed by the teachers can support a conducive learning atmosphere (Verdina, Gani & Sulastri 2019)

The model Problem-Solving Laboratory (PSL) is a learning model developed by the Department of Physics at the University of Minnesota USA. The PSL model facilitates students to carry out practical activities that enable them to practice making decisions based on the physics problems presented. The solve physics problems are done in the laboratory, so that requires students to make decisions based on their physics knowledge. The PSL model makes it possible to train and develop the critical thinking skills of students. The PSL learning model steps according to Heller and Heller (2012) consists of an opening moves: the teacher prepares student work groups and prepares laboratory activities; middle games: students do practical activities, and the teacher observes and evaluates practical activities; end games: teachers and students discuss the results of laboratory activities.

Problem-solving laboratory learning model will be applied to temperature and heat topic. The selection of this topic is tailored to the demands of the curriculum that requires training and developing high-level thinking skills of students, compatibility with the model to be used and many of its applications in daily life. In addition, the learning process of temperature and heat topics is still explanatory, decreasing, and applying formulas math in answering questions and still rarely practiced in laboratory activities.

Previous research related to the application of the PSL model in improving students' thinking skills has been done. The PSL model can improve students' problem-solving skills (Malik et al. 2019b; Burnham 2013; Putri & Sutarno 2012). Research of Tishchenko (2016) concluded that the PSL model can increase the active use of information technology. Malik, Handayani and Nuraini

(2015) prove that the PSL model can be applied as an effort to improve student science process skills as well as research results Muhajir et al. (2015) that the PSL model can be applied as an effort to improve student scientific literacy skills. The PSL model has a significant effect on improving student learning outcomes (Putri et al. 2019; Hariani 2014; Hadija 2014; Azizah & Edie 2014). The application of the PSL learning model can improve students' conceptual understanding (Nurbaya, Nurjannah & Werdhiana 2012).

Several previous studies, the PSL model has not been used to improve a variety of other students' thinking abilities such as critical thinking, creative thinking, scientific communication, and collaborative. The novelty of this study, when compared with previous research on how the PSL model can improve students' critical thinking skills related to the topic of temperature and heat.

RESEARCH METHODOLOGY

The method used in this study was pre-experiment with the one-group pretest-posttest design. The population of this study was class X Muhammadiyah 1 Garut High School, the sample was selected by purposive sampling technique, with a sample of one class X-2 amounting 30 people.

Data retrieval uses several instruments consisting of 1) Observation sheet used to observe the activities of teachers and students during the learning process by applying the problem-solving laboratory model. The observation sheet is filled in with a checklist that serves to assess the implementation of learning, which is equipped with comments and suggestions filled in by the observer regarding strengths and weaknesses from the model PSL during the learning process. The number of teacher and student activities in learning by applying the PSL model in the first, second and third meetings was each 46 items. 2) Tests of critical thinking skills in the form of eight essay questions about the temperature and heat outlined in the pre-test and post-test. The test is used to determine each indicator contained in critical thinking skills. Indicators of critical thinking skills used to measure critical thinking skills in this study according to Ennis (1987) consist of (1) basic clarification with sub-indicators analyzing arguments and answering clarification questions, (2) the basis for making decisions or support with sub-indicators considering source credibility and considering observations, (3) inference with sub-indicators makes and considers induction, makes value statements based on facts, makes consequence-based value statements, (4) further clarification with sub-indicators assessing definitions.

Analysis of observational data on the activities of teachers and students on the implementation of the PSL model is processed by giving scores to each item. Fill in the observation sheet by giving a checklist and comments by the observer in the observation sheet column for each activity carried out by the teacher and students during the PSL model learning. The scale used in the observation sheet is the Likert scale. The data analysis steps carried out consist of 1) Calculating the number of indicators of teacher and student activities carried out at each stage of the PSL model. Reference assessment includes not implemented (0), very lacking (1), lacking (2), sufficient (3), good (4), very good (5) (Riduwan, 2012). 2) Determine the amount of implementation of teacher and student activities on each assessment criteria and present them in table form. 3) Processing the score obtained in the form of a percentage (%) using the formula of the percent value sought or expected = the raw score obtained divided by the maximum ideal score multiplied by 100%. 4) Determine the criteria for the implementation of teacher and student activities when applying the PSL model following the opinion Purwanto (2009) shown in Table 1.

TABLE 1. Criteria for implementation PSL model learning

Value range	Criteria
≤ 54%	Very less
55% - 59%	Less
60% - 75%	Medium
76% - 85%	Good
86% - 100%	Very good

TABEL 2. Implementation of teacher and student activities at each step of the PSL model

Step of PSL Model	1st Meeting		2nd Meeting		3rd Meeting		Average		Interpretation	
	Teacher (%)	Student (%)	Teacher (%)	Student (%)	Teacher (%)	Student (%)	Teacher (%)	Student (%)	Teacher	Student
Preliminary	76	70	90	82	98	88	88	80	Very Good	Good
Opening moves	78	77	88	85	92	88	86	83	Very Good	Good
Middle games	67	67	82	82	90	85	79	78	Good	Good
End games	80	75	82	80	87	87	83	81	Good	Good
Average	75	72	85	82	92	87	84	80	Good	Good
Interpretation	Medium	Medium	Good	Good	Very Good	Very Good	Good	Good		

Scoring guidelines for tests of critical thinking skills are scores 4, 3, 2.1 with a maximum score of 4 and minimum scores 1. Instruments of critical thinking skills before being used for pretest and posttest are tested and analyzed using the Annates 4.0.9 software program. The increasing students' critical thinking skills obtained from the results of the pretest and posttest are then calculated using the gain formula that is normalized and interpreted according to the criteria Hake (1998). The data normality test was carried out using the Lilliefors test, then the hypothesis test was carried out using the t-test. Normality test and hypothesis test use a significance level (α) of 5%.

RESULTS AND DISCUSSION

Results

Implementation of model Problem-Solving Laboratory (PSL)

Observation data on the implementation of teacher and student activities at each step of the PSL learning model at each meeting is shown in TABLE 2.

The implementation of activities of teachers and students increase at each step of the PSL model at each meeting. The data in Table 2 shows the highest average teacher activity obtained at the preliminary stage, with a percentage of 88% and categorized very well. The lowest average teacher activity was obtained at the stage of the middle game, with a percentage of 79% and categorized as good. The highest average student activity was obtained at the opening moves stage with a percentage of 83% and categorized as good. The lowest average student activity was obtained at the stage of the middle game with a percentage of 78% and categorized as good.

Enhancing Critical Thinking Skills (CTS)

The average value of pretest, posttest, and N-gain of students' critical thinking skills for each sub concept related to the topic of temperature and heat can be seen in TABLE 3.

TABLE 3. Pretest, posttest and n-gain scores of students' thinking skills for each sub concept

No	**Indicator of CTS**	**Average**			
		Pretest	***Posttest***	***N-gain***	**Interpretation**
1	Effect of heat on the temperature of the substance	34	76	0.62	Medium
2	Effect of heat on the form of matter	37	81	0.71	High
3	Heat transfer	30	71	0.59	Medium
Average		**34**	**76**	**0.64**	**Medium**

The increase in the highest critical thinking skills of students in the sub concept of heat effect on the form of matter included in the high category of 0.71 and the increase in the lowest critical thinking skills of students in the heat transfer sub concept included in the medium category of 0.59. The average results of the overall pretest for the three sub-concepts amounted to 34 and posttest overall for the three sub-concepts amounting to 76. Overall N-gain increase for the three sub-concepts amounted to 0.64 with the medium category.

The average score of the pretest, posttest, and N-gain for each sub-indicator of students' critical thinking skills can be seen in TABLE 4.

TABLE 4. Pretest, posttest and n-gain scores for each sub-indicator of students' critical thinking skills

No	Indicator of CTS	Sub indicator of CTS	Enhancing of CTS			
			Pretest	***Posttest***	**N-Gain**	**Interpretation**
1	Basic clarification	Analyze the argument	38	72	0.55	Medium
		Answering clarification questions	30	78	0.69	Medium
2	Basic in making decisions	Assessing source credibility	35	81	0.71	High
		Assess observation reports	37	81	0.70	High
3	Inference	Induction: investigative activity	38	82	0.71	High
		Make a value statement based on facts	27	68	0.56	Medium
		Make a value statement: consequences	26	66	0.54	Medium
4	Further clarification	Assess definitions	37	80	0.68	Medium
Average			**34**	**76**	**0.64**	**Medium**

Pretest, posttest and N-gain scores of students' critical thinking skills for each sub-indicator increased. The sub-indicator that experienced the highest increase was assessing source credibility and induction: investigative activity was 0.71 with a category of high increase. While the sub-indicator that experienced the lowest increase was making a consequence-based statement of 0.54 with the medium category.

The average of pretest for each sub-indicator was 34, posttest was 76 and N-gain was 0.64 including the medium category. The improvement of students' critical thinking skills for all indicators after being applied to the problem-solving laboratory model has increased with the medium category. The details of the number of students who experienced an increase in students' critical thinking skills in each category consisted of a high category of one student with a percentage of 3%, there were 29 students including the medium category with a percentage of 97%, and no students included in the low category with a percentage 0%.

The normality of the pretest and posttest data is done through a normality test. Based on calculations obtained Lilliefors value for pretest data shows that the data pretest students' critical thinking skills related to the topic of temperature and heat are normal distributed where L-count (0.076) < L-table (0.161). The posttest data of students' critical thinking skills related to the topic of temperature and heat were normaly distributed with L-count (0.066) < L-table (0.161).

Hypothesis testing is intended to test the accepted or rejected of the hypothesis proposed. The results of the normality test for pretest and posttest data on critical thinking skills are normally distributed, hypothesis testing is done using the t-test. Based on the recapitulation calculation of the results of hypothesis testing using the t-test above, it is found that t-count is 21.560 and t-table is 2.045 with a significance level of 5%. The data shows that the t-count is greater than t-table (t-count > t-table) so that the hypothesis decision can be obtained (H_1) accepted and (H_0) rejected. Thus, the problem-solving laboratory model can improve students' critical thinking skills on the topic of temperature and heat.

Discussion

Implementation of model Problem-Solving Laboratory (PSL)

The results of the study are based on observations during the implementation of the PSL model in class, the factors that influence learning at the first meeting are students who are still difficult and confused in carrying out learning with the planned stages. Students are not accustomed to carrying out real-world problem-based learning in daily life that is solved or solved through activities laboratory. Students' confusion in implementing this model makes the teacher continue to give direction at each step and remind students when the stages change.

Unlike the case with the second and third meetings, the learning process that was implemented experienced a good increase. Students look more active, teamwork, determine laboratory activities plans, laboratory activities and analysis of laboratory results by involving team discussions, conveying and explaining conclusions and evaluating predictions with confidence. Based on the findings at this meeting, the factors that influence the increasing activity of teachers and students in the second and third meetings, namely students were familiar and understand each stage of the problem-solving laboratory learning model. The average activity of teachers and students during learning using the PSL learning model is categorized as good.

Students' skills in solving problems are actualized along with the learning process carried out through practical activities that make students able to use practical tools, apply concepts to solve the problem and add their experience related learn in activities laboratory. The problem-solving laboratory model is a problem solving practical model that has an important function to place knowledge into practice based on students' mental activities (Tishchenko 2016).

The lowest stage of the implementation of the problem-solving laboratory model is at the stage of the middle game. This is because, at the stage of the middle game, students need time in planning practical activities such as making and arranging practicum procedures and collecting data so that the time for the next stages such as the time data analysis is limited. Malik, Handayani and Nuraini (2015) ay the reason for this stage is lowest because students are still not skilled in making their own experimental plans and are still not confident in setting up experimental procedures so that they still need direction before practicum. Besides, Sujarwata (2009) revealed that the limitations of practicum tools can also affect activities in laboratory activities.

The opening moves stage is the highest stage because some students are able to solve the problems presented to make practical and predictive goals. Students can carry out practical activities to prove the predictions made. The problems presented train students to actively critical think in solving them. This is because according to Hariani (2014) intended to provide breadth to students to actively think and practice skills in planning and resolving the problems they face. The development of understanding, skills, and scientific attitudes of students can be more optimal. Ellianawati & Subali (2010) explained that this PSL model fosters the independence of students because it is given the power to practice so that it is not fixed on the sequence of experiments as given by the existing practicum guidelines. The role of the teacher is only as a facilitator and reviews the implementation and results of the experiment.

PSL models play an important role in train and develop students' attitudes relating to problem-solving, thinking, group work, communicating, receiving and providing information with other students can increase (Putri & Sutarno 2012). The linkage of the problem-solving laboratory model with critical thinking skills including the opening moves stage can improve the ability to analyze the argument by identifying reasons that are not stated and answering questions of clarification. The middle game's stage can improve the ability of source credibility based on criteria, induce, make value statements based on facts and make value statements based on consequences. The stage of end game can improve the ability to assess definitions.

Enhancing Critical Thinking Skills (CTS)

Students' critical thinking skills after going through the learning process using the problem-solving laboratory model on the three sub concepts for three meetings experienced an increase in the medium category. The three sub-concepts are learned through activities laboratory that involve students actively to carry out practical activities. Students can train and develop critical thinking skills through various activities to apply concepts to solve problem-related to the three sub-concepts. The N-gain in the sub concept of the heat effect on the form of the substance obtaining the highest N-gain is 0.7 in the high category. The lowest N-gain is obtained by the third sub concept of heat transfer of 0.59 with the medium category. This is because in each sub concept carries out different practicum with each other. Each practicum has varying degrees of difficulty that require critical thinking skills in solving problems presented. Through the problem-solving laboratory model, students will not feel bored but will be motivated to find answers to any problems encountered in everyday life (Hadija 2014).

Overall N-gain students' critical thinking skills are in the medium category. The N-gain sub-indicator makes the consequence-based value statement the lowest sub-indicator with the medium category. Students when making conclusions are not accompanied by strong scientific reasons. Predictions that have been made are not related to the conclusions obtained. According to Siegel (2010) one of the keys to critical thinking is the skill in giving an assessment of reason. The highest N-gain occurs in sub-indicator of the investigation activity aspect with a high category. This is because at each meeting students are always involved to carry out activities laboratory so the investigation activity aspects in data collection activities make students familiar and trained. Laboratory activity with problem-based laboratory instruction trains students to make measurable changes in problem-solving skills and metacognition (Sandi-urena, Cooper & Stevens 2012).

Improving students' critical thinking skills using the problem-solving laboratory model can be obtained hypothesis decision (H_1) accepted and (H_0) rejected. In addition, it has also been proven by the results of N-gain of 0.49 which indicates that the problem-solving laboratory model can improve students' critical thinking skills in the topic of temperature and heat. The advantages of the problem-solving laboratory learning model are one of the factors that influence it, namely the problem-solving laboratory learning model can enable students to learn to use the equipment, learn how to design experiments, and get real experiences of what scientists be doing (Heller & Heller 2012). In addition, the development of students' understanding, skills, and scientific attitudes can be more optimal if given flexibility to students to actively think and practice skills in planning and solving problems they face (Hariani 2014).

The application of the problem-solving laboratory model can improve students' critical thinking skills. Subsequent research allows the problem-solving laboratory model to improve other skills of students such as creative thinking skills, scientific communication skills, and collaborative skills.

CONCLUSIONS

We have succeeded in conducting research to enhance students' critical thinking skills related to temperature and heat through the application of problem-solving laboratory model. Based on the results of the analysis of the observation sheet, it was obtained that the activity of the teacher in the good category was 84% and the activity of the students was 80% in the good category during learning by applying the model problem-solving laboratory. Students' critical thinking skills related to the topic of temperature and heat have increased after a problem-solving laboratory model has been applied with N-gain of 0.64 in the medium category.

The application of the problem-solving laboratory model requires adequate time management and conditioning of students during activities laboratory. The teacher must design activities laboratory according to the planned time. Student activities at the stage of the middle game (student data analysis) students do not understand how to interpret the practicum data in graphical form. Therefore, the teacher must be able to guide and direct the way to package the form of analysis questions that are easy to understand and add information on graphical forms such as what must be made and equipped with descriptions as a form of interpretation of laboratory activities results.

Aspects of critical thinking skills of students make consequence-based statements are sub-indicators with the lowest N-gain compared to other sub-indicators. Therefore, teachers should train these skills in the context of everyday life related to the application of the concept of temperature and heat. Students are required to try to give good and bad statements and judgments based on experiences experienced and associated with the concepts learned.

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