JSER 2021, 5(1), 31-37

JSER

Journal of Science Education Research

Journal homepage: www.journal.uny.ac.id/jser

Analysis of student's critical thinking skills and creativity after problem-based learning with STEM integration

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Keywords:
PBL, STEM, critical, creative

ABSTRACT

Problem based learning (PBL) is one of the ideal learning models to meet the goals of 21st century education. It involves the 4C principles of critical thinking, communication, collaboration, and creativity. This study aims to analyze students' critical and creative thinking skills after the use of STEM integrated PBL. This type of study is a mix method research with sequential explanatory design. The research subjects are 100 students of class XI IPA Christian Tri Tunggal Senior High School. The research instruments were written test questions, observation, interviews, and documentation. The results of the validation of the instruments by experts show a Cronbach Alpha score of 0.79. The data analysis is conducted through quantitative descriptive accompanied by t-test and N-gain test. The results of the analysis show that students' critical thinking skills achieve a good criteria with the highest achievement in the aspect of providing simple explanations. Students' creative thinking skills achieve a good criteria with the highest achievement on the flexibility aspect, namely providing various interpretations of a discourse, story, or problem. Hence, STEM integrated PBL can develop students' critical and creative thinking skills.

INTRODUCTION

The National Education Association has identified 21st century skills as "The 4Cs" skills. The latter covers critical thinking, creativity, communication, and collaboration. Critical thinking skills are skills for conducting various analysis, assessments, evaluations, reconstruction, decision-making that lead to rational and logical actions (Roberts, 2012). On the other hand, items of higher order thinking skills (HOTS) are questions, exercises, or ill-defined/ill-structured problems, namely questions, exercises, or new problems for students and require solutions more than just the application of knowledge. Solutions require analysis, synthesis, systems thinking, decision making, problem solving skills, relationship making, and critical evaluative thinking. These HOTS items include the application of theory or knowledge to dissimilar situations.

Afriana et al. (2016) stated that Science Technology Engineering Mathematics (STEM) is currently an alternative science learning that can develop the potential of the younger generation to be able to face the challenges of the 21st century. The STEM approach makes students able to solve problems better. STEM makes students become innovators, inventors, independent, thinkers, logical, and literate towards technology (Suhery, 2017). Through STEM integrated PBL students can solve problems, think logically, and be technology literate (Oktavia & Ridlo, 2020). A study by Cahyaningsih and Roektiningroem (2018) states that increasing critical thinking skills and cognitive learning outcomes of students can be done through STEM integrated PBL. In addition, according to a study by Kristiani et al. (2017) state that STEM integrated PBL can develop students' creative thinking skills.

The research results of Sari et al. (2019) reveal that efforts are needed to reform education in order to improve the quality of students who have character and critical thinking in facing the era of disruption through student-centered learning. Becker and Park (2011) analyze learning that can improve 21st century skills, namely learning based on STEM. Based on a study by Setiyono (2011), it is found that the average creative thinking skills of students were in the less creative category. In addition, the learning given to students still did not implement integrated learning, or only monodicipline learning, even though solving problems in everyday life cannot be solved with just one field of knowledge, but must be multidisciplinary. Meanwhile, based on the results of a meeting of teachers in chemistry subjects in Semarang city, the problem that often arises is that students have not been able to apply chemical knowledge in everyday life, so when

faced with questions that require HOTS they have not been able to solve it optimally. In general, chemistry learning which is still ongoing today tends to be teacher-centered.

A preliminary observations at SMA Tri Tunggal Semarang show that chemistry learning is generally still teacher-oriented. Students tend to accept the teacher's explanation without having to know the meaning of the lesson. Chemistry tends to be studied as a product, memorizing concepts, theories, and laws. In the end, students have difficulty answering questions related to social issues. One way to overcome this problem is by updating the education system that supports renewal in science learning to improve students' critical and creative thinking skills. When the science learning process takes place the teacher does not train HOTS of students. They find it difficult to apply these concepts in everyday life to solve various problems. A student does not sufficiently master theories, but must also be willing and able to apply them in everyday life (Ariyatun, 2019).

PBL is one of the ideal learning models to meet the goals of 21st century education because it involves the 4C principles. The results of a study on project-based learning (PjBL) and PBL indicate that students have an advantage to learn factually using PjBL and PBL compared to learning in more traditional classrooms. Trilling and Fadel (2009) explain that learning with these models takes quite a long time showing that the learning outcomes and various 21st century skills of students are significantly different from classes that use traditional methods. However, in order for PBL to run well, teachers must design an activity plan according to the interests and needs of students, and of course according to the curriculum. It may not be easy to apply the two learning models with a standard time allocation per hour of 45 to 50 minutes as usual, but it can be pursued with alternatives to learning activities that are planned as well as possible. (Rosa & Pujiati, 2017; Savery & Duffy, 1995; Wood, 2003) state that PBL ultimately requires a change in the role of the teacher from being a source of knowledge to becoming a trainer and facilitator.

It is very important to train critical and creative thinking skills because these skills are not carried from birth (Redhana, 2010). Especially in senior high school, these skills have not been handled properly so that the critical and creative thinking skills of high school graduates are still relatively low. The low critical and creative thinking skills of graduates come from elementary schools to tertiary institutions (Reta, 2012). Critical and creative thinking skills have become the goals or demands of all subjects, including chemistry. The development of critical thinking skills can occur because chemistry can provide complex problems that can challenge students to apply a number of skills, such as analyzing and proposing arguments, providing clarification, providing evidence, giving reasons, analyzing the implications of an opinion, and drawing conclusions based on data or information. In other words, chemistry subjects can act as a vehicle to develop students' critical thinking skills. On the other hand, this is the opportunity for students to increase their understanding of chemical content.

Given the importance of critical and creative thinking skills for students, it is very important to develop learning activities that can improve students' critical and creative thinking skills. One of the learning activities that is considered effective in improving critical and creative thinking skills is PBL. PBL is an alternative learning that is student-centered and has been developed recently. Tiwari et al. (2006) state that PBL provides an alternative learning so that students' critical thinking skills can be develop.

METHOD

This was a mix method research with sequential explanatory design with quantitative research as the primary data are in the form of the test results of creative and critical thinking skills during the pre-test and post-test followed by qualitative research, which strengthens the quantitative data in the form of observation and interview. This research was conducted at Tri Tunggal Christian Senior High School, Semarang. The research subjects were 100 students of class XI IPA. In this study, the subjects were given treatment in the form of STEM integrated PBL. After being given the treatment, the subjects were given a written test related to critical and creative thinking questions. The research instruments developed included written test questions, observation, interviews, and documentation.

The data collection technique in this study was through the open ended problem type test technique, which was declared valid by two material experts and had a reliability of 0.72. The data analysis is conducted by calculating the pre-test and post-test scores, t-test, and N-gain, and using quantitative descriptive. The ability to think critically and creatively is measured based on indicators of critical and creative thinking skills adopted from (Tawil & Liliasari, 2014). Then, the analysis of students' critical and creative thinking abilities was carried out by calculating the scores for each indicator of critical and creative thinking skills from the answers to the test questions. The criteria for the achievement of students' critical and creative thinking skills for each indicator with percentages of $84\% < X \leq 100\%$; $68\% < X \leq 84\%$; $52\% < X \leq 68\%$;

36% < X ≤ 52%; and 36% ≤ X < 0% are categorized as very good, good, fair, not good and poor, respectively. Meanwhile, to strengthen the results found, the researchers conducted interviews with respondents.

RESULT

Analysis of Critical Thinking Skills

Indicators of students' creative and critical thinking skills being measured in this study are integrated into a cognitive learning outcome assessment test kit with the level of questions used from C2 (understanding) to C5 (evaluation). Students' creative thinking skills are assessed through written test answers. The written test questions used consisted of 10 numbers on critical thinking skills and 8 numbers on critical thinking skills with an allocation of 90 minutes each. The written test answers are then analyzed for each indicator with a rating range of 0 to 3 on each item number. Data related to students' creative thinking skills are obtained from written test instruments as a source of quantitative data and observation sheets as a source of qualitative data. Both instruments are strengthened and clarified by analysis of the results of written tests and interviews conducted with students.

The overall critical thinking achievement is obtained by calculating the average percentage of students who answered correctly on each item. Acquisition of research data related to critical thinking skills in each aspect is obtained by calculating the percentage of the test results for each indicator then comparing the score obtained by each student with the maximum score and looking for the average score of the critical thinking skills of each indicator. The results of the test are then analyzed on every aspect of critical thinking skills. The results of the analysis of the mean critical thinking skills of students in each aspect are summarized in Table 1.

Table 1. Average score of critical thinking skills

No.	Critical Thinking Aspects	Average Score		N-gain	Category
		Pre-test	Post-test		
1.	Building basic skills	43.63	73.60	0.35	Moderate
2.	Giving a simple explanation	45.17	65.50	0.45	Moderate
3.	Concluding	36.90	76.10	0.14	Low
	mean	41.90	71.73	0.31	Moderate

Table 1 shows that for the pre-test and post-test results the highest percentages are obtained for the aspects of giving a simple explanation and concluding, i.e.: 45.17 and 76.10, respectively. The second highest score of the pre-test and post-test results is obtained for the aspect of building basic skills, i.e.: 43.63 and 73.60, respectively. Finally, in third place for the pre-test and post-tests results are obtained for the aspects of concluding and providing a simple explanation, i.e.: 36.90 and 65.50, respectively. Based on the category of the critical thinking skills, the aspects of building basic skills, giving a simple explanation, and concluding are in the high, medium, and high categories, respectively. The criteria classification for critical thinking skills is presented in Table 2.

Table 2. Criteria for students' creative and critical thinking skills

No.	Criteria	Interval	Number of Students	
			Critical Thinking	Creative Thinking
1.	High	66.6 < p ≤ 100	64	54
2.	Moderate	33.3 < p ≤ 66.6	32	40
3.	Low	0 < p ≤ 33.3	4	6

Table 2 shows the number of students with high, moderate, and low critical thinking skills is 64, 32, and 4 students, respectively. The mean score of students' critical thinking skills is 71.73, which is in the high category. The use of STEM integrated PBL is said to be successful if it meets the requirements of completeness of the critical thinking skills test results, namely if there is a difference in the average score of students' critical thinking skills before and after the treatment.

The hypothesis testing uses the one sample t-test with the help of the SPSS software. The sig value obtained is -19.680 < -1.98326 so that Ho is rejected and Ha is accepted. Hence, there is a difference in the results of the critical thinking skills test between before and after the application of STEM integrated PBL in chemistry. STEM integrated PBL is carried out by presenting problems, questions, facilitating investigations, opening dialogues with students, and actualizing student environmental literacy and creativity (Farwati et al., 2018; Rosidin et al., 2018). In the learning phase, STEM integrated PBL allows the elaboration, cooperation, and collaborative interaction of students in analyzing problems and the reporting process. Through STEM

integrated PBL students show positive attitudes, achieve integrated conceptual and procedural knowledge, and show active behavioral intentions (Lou et al., 2011).

The results of the analysis of several research articles show that the implementation of STEM in learning is very popular because it hones creative, cognitive, and explore thinking skills, utilize technology, and apply knowledge (Capraro et al., 2013; Sari et al., 2019). In its implementation, STEM can be integrated with PjBL, PBL, discovery based learning, and inquiry based learning models (Casad et al., 2017; LaForce et al., 2017; Redkar, 2012; Sari et al., 2019). The research results of Sumarni *et al*. (2019) conclude that STEM-PBL was able to develop students' cognitive and creative thinking skills with a good criteria, with the highest achievement on indicators of concept understanding and the ability to view information from a different point of view, respectively.

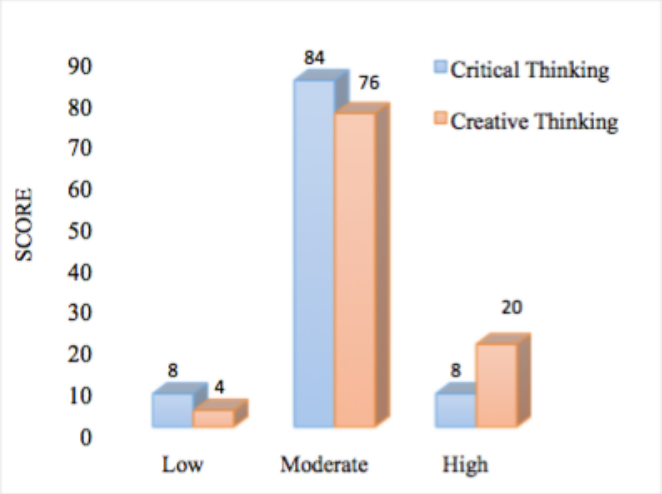

Figure 1. The N-gain analysis of students' creative and critical thinking skills

The magnitude of the increase in students' critical thinking skills is obtained from the calculation of the N-gain formula (g) by comparing the pre-test and post-test scores. The average pre-test and pot-test scores is 41.90 and 71.73, so that the value of g is 0.51, which is in the moderate category. Moreover, the N-gain category is summarized in Figure 1. The figure shows that there are 8 students who experienced an increase in critical thinking skills in the high category, whereas in the medium and low categories there are 84 and 8 students. These results are also in line with the results of the critical thinking observers during the learning process. The results of the analysis of students' critical thinking skills are presented in Table 3.

Table 3. The results of the observation of creative and critical thinking skills

No.	Criteria	Number of Students	
		Critical Thinking	Creative Thinking
1.	Very Good	13	4
2.	Good	53	60
3.	Good Enough	24	28
4.	Not Good	10	8

Table 3 shows that there are 13; 53; 24; and 10 students who have very good, good, good enough, and not good criterias in creative thinking skills. So that solving problems requires the ability to think critically. A person's critical thinking skills can be seen from several visible characteristics. Indicators of critical thinking skills in this study include students' abilities in: (1) providing simple explanations, (2) building skills, (3) making inferences, (4) making further explanations, and (5) arranging strategies. The assessment of students' critical thinking skills is used to improve the learning process, one of which is by using an open-ended problem test and an assessment based on students' answers. The test of critical thinking skills includes questioning, guessing the cause and effect of an event, and improving the outcome. Students' critical thinking skills in this study are developed through activities in constructing their own knowledge learned from learning activities such as discussing and/or practicum in problem solving.

The application of STEM-PBL requires a change in the learning model from teacher-centered to student-centered learning. Moreover, it requires a change from individual to collaborative learning and emphasizes creativity and problem solving in science knowledge applications (Suhery, 2017).

Analysis of Creative Thinking Skills

Indicators of students' creative thinking skills measured in this study, include: fluency, flexibility, elaboration, and originality. Observations of creative thinking skills are carried out during the learning process, which are carried out for five times. Observations are conducted by two observers for each observation. The data related to students' creative thinking skills are obtained from written test instruments and obervation sheets as sources of quantitative and qualiaive data, respectively. Both instruments are strengthened and clarified by analysis of the results of written tests and interviews conducted with students. The criteria of creative thinking skills of students is measured based on the total score obtained from the written test results. The results of the creative thinking skills tests are then analyzed for every aspects. The results of the analysis of the mean creative thinking skills of students in each aspect are given in Table 4.

Table 4. Average score of creative thinking skills

No.	Aspect	Score Average		N-gain	Criteria
		Pretest	Posttest		
1.	fluency	39.40	74.10	0.63	Moderate
2.	flexibility	40.50	77.93	0.56	
3.	elaboration	35.87	68.35	0.46	
4.	originality	40.50	78.50	0.58	
	Average	39.76	74.72	0.56	Moderate

Table 4 shows that there is a significant difference between the mean pre-test and post-test scores on the creative thinking ability test of students. The mean score of the pre-test is 39.76 in the low category, while for the post-test, the mean score is 74.72 in the moderate category. The criteria for creative thinking skills is presented in Table 2. Table 2 shows that the number of students with high, medium, and low criterias of creative thinking skills of class XI MIPA are 54; 40; and 6 students, respectively. Overall, the mean creative thinking skills of students is 74.72 in the high category. Meanwhile, the increase in students' creative thinking skills is obtained from the calculation of g by comparing the pre-test and post-test scores. From the calculation, the average values of the pre-test and post-test are 39.8 and 75.07, respectively, so that the value of g is 0.59, which is in the moderate category. The N-gain category is summarized in Figure 1.

STEM integrated PBL is said to be successful in improving students' creative thinking skills, namely there is a difference in the average scores of students' creative thinking skills before and after the application of STEM integrated PBL. The hypothesis testing uses the one sample t-test with the help of the SPSS software. From the results of the t-test output, it is obtained that the sig value has a value of -19.680 < -1.98326 so that Ho is rejected and Ha is accepted. Hence, there is a difference in the results of the test for the ability to think creatively before and after the application of STEM integrated PBL. These results are in accordance with the acquisition of observations of creative thinking skills presented in Table 3.

Analysis of the creative thinking skills possessed by students based on the results of written tests (quantitative data) and observation sheets (qualitative data) as a whole has the same tendency. The answers given by students to the questions given on the written test results on each indicator of creative thinking skills are strengthened by the results of interviews conducted. The highest percentage of creative thinking skills on colloid material is on the originality indicator, while the lowest average score is on the elaboration indicator. Flexibility indicator on hydrolysis material is better than the fluency indicator.

The results of this analysis and measurement show that the qualitative data strengthen the quantitative data. The instrument used to measure the creative thinking skills of students supports each other and provides information that is not much different. Quantitative and qualitative data provide consistent results and can be used together to measure the creative thinking skills of students. The measurement of creative thinking skills possessed by students can be done in the form of a written test in open-ended questions (Fatah et al., 2016; Santofani & Rosana, 2016; Susanto & Suryadarma, 2019; Wibowo et al., 2013; Zubaidah, 2016). Test instruments, observation sheets, and interviews can be used together to measure creative thinking skills possessed by students (Kadir *et al*., 2017). The creative thinking skills of students is high indicating that students have the ability to foster new ideas and understanding, turn on their imagination, and express new possibilities (Rosidin et al., 2018). By having high creative thinking skills, students have the ability to solve problems (Kadir & Satriawati, 2017).

CONCLUSION

The overall students' critical thinking skills produces a mean score of 71.73, which is in a high criteria. This shows that the ability of students in building basic skills, providing simple explanations, interpreting

data, and concluding is very good. Thecritical thinking skills in this study is influenced by the learning model used, namely STEM integrated PBL that is inseparable from the social context and focuses on mastery of material in preparing knowledge that must be understand. The students' creative thinking skills produces a mean score of 74.72, which is in the high criteria. This shows that students' flexibility, fluency, originality, and elaboration are developing very well. The application of STEM integrated PBL helps students gain experience from learning the situations, solving complex problems, and gain a deep understanding of chemical materials to improve HOTS, especially creative thinking skills.

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