



ETHNO-STEM PROJECT-BASED LEARNING: ITS IMPACT TO CRITICAL AND CREATIVE THINKING SKILLS

W. Sumarni^{*1} and S. Kadarwati²

^{1,2}Dept. of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang

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ABSTRACT

Guiding students to think critically and creatively is a crucial part of the educational process to meet the required skills in the 21st century. Besides, attention to the local culture especially that is closely related to the scientific concepts needs to be strongly emphasized. Due to those two aspects i.e. creative and critical thinking as well as attention to local culture, the ethno-STEM project-based learning for high school students has been implemented and its impact on students' critical and creative thinking skills has been investigated. This study involved 230 students from seven high schools in Central Java, Indonesia. The data collection was carried out through a set of instruments to reveal the students' critical and creative thinking skills. The instruments were declared as valid based on the experts' judgment and showed an Alpha Cronbach score of 0.79 before use. The results showed that the ethno-STEM project-based learning was able to improve the average critical and creative thinking skills of students in all indicators varying from low to medium categories. The improvement of students' critical thinking skills was observed by the achievement of the N-gain score, i.e. 52 students (22.6%) achieved a high category, 102 students (44.4%) achieved a medium category, and 76 students (33.0%) achieved a low category. Moreover, an increase in the creative thinking skills was also observed, indicated by the N-gain score, i.e. 63 students (27.4%) were at a high category, 109 students (47.4%) were at a medium category, and 58 students (25.2%) were at a low category. In conclusion, the ethno-STEM project-based learning showed a significant effect on the improvement of students' critical and creative thinking skills.

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Keywords: critical and creative thinking; ethno-STEM; ethno-STEM project-based learning

INTRODUCTION

Market demands in the 21st century require employees to have capabilities in critically overcoming problems and producing creative solutions (Nakano & Wechsler, 2018). At the same time, they must also have a full mastery in sciences, technology, engineering and mathematics (Liliawati et al., 2018). Therefore, teaching-learning processes must meet the standard needs of graduates in this century by providing students with high-level thinking skills.

High-level thinking skills, especially critical and creative thinking skills, are urgently needed in utilizing the students' knowledge for problem-solving and decision making in various fields of life (Retnawati et al., 2018). Thinking differently and critical thinking are very important for students to make a decision when they face several options (Fields & Bisschoff, 2014). However, low-level thinking skills were often used in many learning processes at schools (Saido et al., 2015). The students' critical and creative thinking potential in the classroom's learning process was not well-developed. The preliminary observations in several high schools in Semarang (Central Java,

*Correspondence Address

E-mail: worosumarni@mail.unnes.ac.id

Indonesia) showed that teacher-centered learning was pre-dominant. Most of the teaching/learning process was undertaken in classrooms, thus memorizing concepts was emphasized instead of stimulating the students' curiosity in the teaching/learning in a laboratory. The students tended to accept the "final" concepts and were encouraged to fully believe in what being taught. They were not experienced with any process of proving how to obtain the concepts. Furthermore, the assignments and test questions mostly did not require higher-level thinking. Consequently, the students were not well-trained to solve a 'why' question. The students were rarely requested to evaluate why a process takes place. The opportunities to convey creative ideas or designs to solve the problems encountered were also rarely provided in the teaching/learning process. Moreover, a different perspective was rarely used to solve a certain problem. This condition was also observed in the previous study (Wijayati et al., 2019; Sumarni et al., 2019) indicating the urgency of developing the students' critical and creative thinking skills.

Indonesian students showed a low thinking skill indicated by the low score of science as reported by the Programme for International Student Assessment (PISA) in 2018. This indicated that the concern of the learning process has not fully covered the critical, evaluative and creative thinking skills. Recent science teaching and learning, in particular, promoted the ways or techniques on how to understand the concepts, principals, and theories (Darling-Hammond et al., 2019), but it might not yet a means to equip and empower students' critical and creative thinking skills (Rahmawati et al., 2019).

This phenomenon was not only observed in Indonesia but also in other countries worldwide. A study reported in Newsweek (July 10th, 2010) by Bronson & Merryman (2010) showed that a significant decrease in the creativity of American students in the last few decades was observed and represented as a creativity crisis. They correlated this decrease to the standardization of the curriculum, teaching, and assessment at schools. Those seemed pressurized more on memorizing facts and finding the correct answers rather than critically analyzing and evaluating the contents or exploring creative ideas and innovative thoughts.

Critical thinking skills have been considered as an important requirement for responsible human activities. The ability to think critically would allow the students to think rationally in overcoming problems. Moreover, it also helps students to create and develop alternative solutions to the problems. These skills would enable

an individual to make autonomous decisions and question beliefs when they were not based on hard evidence (Dwyer et al., 2014). Critical thinking is also a thinking that tests, questions, connects, and evaluates all aspects of a situation or a problem as a comprehensive introduction. As a result, it could provide better reasoning (Hughes & Lavery, 2015).

Critical thinking involves analysis and evaluation rather than merely accepting ideas or information. It includes an understanding of relationships, similarities, and differences; locating patterns; classifying; understanding cause/effect; observing trends and big ideas; predicting results; considering various perspectives; providing judgments, and asking questions and reasons. For instance, when someone is reading a book or listening to an expression or explanation, he/she will try to understand and find or detect the presence of special, necessary or important things. Likewise, if he/she is given data or information, he/she will be able to make right and correct conclusions while also seeing a contradiction, consistency or irregularities in the information. Advanced critical thinking skills involve six basic cognitive aspects, i.e. interpretation, analysis, evaluation, conclusions, explanations and self-regulation (Hughes & Lavery, 2015). In this critical thinking, someone will do the analysis and reflect the results of his/her thinking.

Like critical thinking skills, creative thinking skills are important cognitive aspects required for meaningful learning in all disciplines. Creative thinking skills aim to synthesize ideas, generate new ideas, and determine the effectiveness of the existing ideas. Creative thinking skills could train students to develop many ideas and arguments, ask questions, acknowledge the truth of an argument, and even enable students to be open and responsive to different perspectives. Creative thinking skills in science learning could open new perspectives for students to provide answers to science problems. Activities such as observation, experiments, and field trips, enable students to learn on their own, more easily understand the lessons, show a positive attitude towards science and develop their creativity. Creativity is operationalized as a combination of fluency, innovation, novelty and imagination (Weisberg, 2015). It plays a key role in the discovery, innovation, and problem-solving that could improve the quality of human life.

Students' critical and creative thinking skills definitely will not develop by themselves. It will develop well if the teacher deliberately encourages students' thinking potential, and mana-

ge them in a planned manner with good learning planning. Learning activities enable students to develop creativity in solving problems. Those activities include connecting different ideas, developing and formulating ideas to solve certain problems. As a result, students' skills in formulating ideas to solve problems, providing original new ideas, developing an idea and being able to make decisions about situations related to science will improve (Wardani et al., 2017).

Regarding the aforementioned problems and the importance of higher-order thinking skills for achieving success, fostering and training students' critical and creative thinking must become a special agenda in the school curriculum. This is following the curriculum in Indonesia. It stated that graduates must have skills and show creative, productive, critical, independent, collaborative, and communicative actions through scientific approaches following what being learned in educational units and other sources independently. Besides, the attention to the local wisdom that has developed since ancient times is strongly needed. This is in line with the previous study that the science learning optimizing local genius, local wisdom or local excellence embraced by local communities would be more appropriate (Kun, 2013).

The STEM education has become a well-known approach among educators due to the improvement of the global technology perspective of the 21st century (Shernoff et al., 2017). STEM is a science-related discipline that requires math as a tool in data processing, and technology as well as engineering as applications of sciences (Afriana et al., 2016). The STEM approach enables students to solve problems better. Moreover, they also would be able to become innovators, inventors, independent workers, logical thinkers, and technology literacy (Afriana et al., 2016). The integration of ethno-STEM approach with a synergetic learning model such as project-based learning (referred to ethno-STEM PBL) would provide a solution to the existing problems. This model involved project-based learning integrated with the four fields of STEM that are based on the local cultures to develop critical, creative, innovative and collaborative thinking skills. Moreover, typical knowledge of society (ethnoscience) is also very important to develop the students' character (Kun, 2013; Sudarmin et al., 2019).

Project-based learning has long been used by many educators as one of the innovative learning practices developing the learning process based on the challenges or problems that lead students to investigate, make decisions, design, and

finally conclude with a product (Uziak, 2016). Previous studies showed that the implementation of PBL would enable the 21st-century educators to create better practices to teach science, technology, engineering, and mathematics (STEM) content (Afriana et al., 2016; Mutakinati et al., 2018). Besides, ethno-STEM PBL showed a significant effect on the students' entrepreneurship (Sudarmin et al., 2019). However, the effects of this ethno-STEM PBL on the development of the students' creative and critical thinking skills were not well reported. On the other hand, ethno-STEM PBL might provide a good teaching practice to improve the students' creative and critical thinking skills. Due to the great importance of those two skills for students, the effect of the implementation of ethno-STEM PBL on the students' critical and creative thinking skills will be clearly explained in this paper.

METHODS

A pre-experimental method with a one-group pretest-posttest design was used in this study. This study was carried out at an academic year of 2017/2018 by involving 230 students from 7 high schools in Central Java, Indonesia. The teachers of those schools have been trained for the technical implementation of ethno-STEM PBL in the teaching-learning process.

The measurement of the students' critical and creative thinking skills (CCTS) was performed by using a test method. The test items were open-ended questions referring to the measurement of creative and critical thinking skills developed by Yoon (2017), Sumarni et al. (2018) and Gelerstein et al. (2016). The measurement of critical and creative thinking skills was also conducted by using the instruments developed by Ventista (2018). The open-ended type question was chosen in this study due to its consideration of the metacognitive aspects, not only the content of the questions. It is well-known that metacognitive has an important role in regulating and controlling the cognitive processes in learning. It encouraged more effective and efficient thinking. In short, metacognitive could lead to high order thinking skills (Coşkun, 2018).

Ten question items were valid in terms of both the content and the construction according to the experts. These items were preliminarily tested to the students other than the subjects of this study. The time was limited for 90 minutes. The high-level cognitive skills i.e. analyzing/synthesizing (C4), evaluating (C5), and creating (C6) were included in the indicators of critical and creative thinking skills.

The reliability of the instruments used in this study was determined using Alpha-Cronbach with an alpha value of 0.79 indicating that the instruments were reliable. This result was following previous studies reported by Fields & Bischoff (2014) in the development of question items to measure students' creativity (called as a Torrance creativity thinking test). The CCTS instruments used in this study showed good validity and reliability, thus were able to produce a

$$N - gain (\%) = \frac{\text{score of posttest} - \text{score of pretest}}{\text{maximum score} - \text{score of pretest}} \times 100\%$$

good measurement of students' critical and creative thinking skills in chemistry teaching/learning. The increase in the students' CCTS (indicated by the N-gain scores) was calculated using Equation 1. The N-gain scores obtained by each student as well as per each indicator of the skills were categorized using criteria presented in Table 1.

Table 1. The Criteria for the Improvement of Students' Critical and Creative Thinking Skills.

Percentage of N-gain (%)	Criteria of CCTS Improvement
70 < % ≤ 100	High
29 < % ≤ 70	Medium
% ≤ 29	Low

RESULTS AND DISCUSSION

The Description of Activities in the Ethno-STEM Project-based Learning

The design of ethno-STEM PBL started by setting the well-defined goals, planning the tasks and the summative assessments. The provided tasks should guide students in producing ideas/solutions for complex problems. Moreover, summative assessments should also demand the use of students' higher-order thinking skills. The syntax explained by The George Lucas Educational Foundation, i.e., starting the lesson with an essential question, designing projects, creating schedules, monitoring the students as well as the progress of the projects, assessing the outcomes, and evaluating the experiences, was used in the implementation of the ethno-STEM PBL conducted by the teachers. In teaching the concepts of colloids, for example, soybean milk was taken as an example of a liquid (dispersed phase)-liquid (dispersing medium) colloidal system. The teaching/learning process in the implementation of the ethno-STEM PBL started with essential questions. The examples of the questions were "what type of colloidal system is soybean milk?", "What is the dispersed phase and dispersing medium of soybean milk, respectively?", "How could we prove that soybean milk is a colloidal system based on its nature?". Such questions would require students to work on an assignment in conducting a certain activity.

Based on those essential questions, the teacher and the students collaboratively designed the project plan. In this study, the planned project was the production of soybean tofu using a simple technology that has been used by the tofu craftsmen. The plan included the applied rules and the

selection of supporting activities in the project completion. Creating schedules was also carried out collaboratively between the teachers and the students. This stage included several activities e.g. plotting a timeline for completing a project, deciding a project completion deadline, inviting the students to propose a new possible technique, providing guidance when the proposed technique was not related to the project, and asking the students to make explanations (reasons) in choosing the technique.

The teacher was responsible for monitoring both the students and the progress of the project. The monitoring process was done using a rubric to record all important activities. Assessing the outcome was carried out to assist the teacher in measuring the students' standard achievement, providing feedback on the level of understanding achieved students, and assisting the teacher in developing the next learning strategy. At the end of the learning process, the teacher and students evaluated the learning experience. The reflection process was done both individually and in groups. At this stage, the students were asked to express their feelings and experiences while completing the project. The teacher and students developed a discussion to improve the teacher's performance during the learning process. As a result, a new finding to answer the problems raised in the first stage of learning activities was found. While completing the project assignments, as is shown in Table 2, the students could collaborate with friends. The teachers provided the students with guidance and help them as facilitators and motivators if they encountered difficulties in completing the tasks. At the end of the projects, the students were asked to present their experiences and project results (Han et al., 2016).

Table 2. The Project Assignments Integrated with Ethno-STEM in the Implemented Project-based Learning.

Topics/Sub-topics	Project Assignments Integrated with Ethno-STEM PBL
Synthesis of colloidal substances	Production of traditional foods (making tofu and <i>cincau</i>). Science: synthesizing colloidal systems, Technology: producing tofu and <i>cincau</i> through a traditional process, Engineering: creative ideas to produce derivative foods with tofu and <i>cincau</i> as starting materials, Mathematics: formulating the composition of components in the production of tofu
Colloidal substances	The production process of Soka tile Science: the types of the dispersed phase and dispersing medium, Technology: tile making and drying equipment, Engineering: creative ideas on the innovation of mixing, drying, and combustion techniques Mathematics: composition of the mixture of raw materials, the relationship of high temperature with the quality of the produced tiles.
Nomenclature of compounds	Production of <i>antor</i> crackers (crackers fried using hot sand). Science: nomenclature of compounds involving in the production of <i>antor</i> crackers i.e. NaCl, H ₂ O, C ₁₂ H ₂₂ O ₁₁ , Al ₂ O ₃ ·nSiO ₂ ·kH ₂ O; SiO ₂ , cellulose, amyllum, charcoal, MSG, Technology: the process of <i>antor</i> (sand-fried) crackers using a clay-made frying pan, Engineering: how to make crispy <i>antor</i> crackers, Mathematics: composition of the raw materials, business opportunities.
Solubility and constant of a solubility product	Preparation of <i>Bledug Kuwu</i> salts. Science: CaSO ₄ and MgSO ₄ are impurities in the <i>Bledug Kuwu</i> salts (equation of constant of solubility product), Technology: the process of the production of <i>Bledug Kuwu</i> salts, Engineering: creative ideas on how to make high-quality <i>Bledug Kuwu</i> salts, Mathematics: calculate the solubility of CaSO ₄ and MgSO ₄ with the given solubility product constants.
Solubility and constant of a solubility product	The hardness of the water. Science: the equation of the constant of solubility product in the formation of CaCO ₃ precipitate in hard water, Technology: the process of water hardness removal through heating, Engineering: creative ideas on how to overcome the formation of crust in the vessel as a result of hard water, Mathematics: calculate the solubility of CaCO ₃ with the given K _{sp} . $\text{CaCO}_{3(s)} \rightleftharpoons \text{Ca}^{2+}_{(aq)} + \text{CO}_3^{2-}_{(aq)}$ $K_{sp} \text{ of CaCO}_3 = [\text{Ca}^{2+}][\text{CO}_3^{2-}] = s^2$
Formation reaction of salts	Removal of crust on heater kettle Science: the concept of the crust caused by hard water, Technology: removal of crust with lime juice, Engineering: creative ideas to get the most effective way to get rid of crust, Mathematics: calculate the solubility of hardly dissolved salts
Saponification reaction	The process of washing <i>batik</i> using <i>lerak</i> extract (traditional detergent) Science: saponification concept, Technology: the process of making soap from <i>lerak</i> seeds instead of detergent, Engineering: creative ideas in formulating ready-to-use <i>lerak</i> liquid as a <i>batik</i> wash from natural ingredients, Mathematics: calculate the number of natural ingredients to get the desired amount of <i>lerak</i> liquid.
Chemical equilibrium	Burning limestones Science: the concept of chemical equilibrium, Technology: technology of limestone combustion resulting in CaO in a <i>tobong</i> Engineering: creative ideas for an effective and efficient combustion process; Mathematics: mathematically predicting a shift in equilibrium

Students' Critical and Creative Thinking Skills

The value of N-gain of students' critical and creative thinking skills after the implementation of ethno-STEM PBL is presented in Figure 1. An increase in the N-gain in both students' critical and creative thinking skills was observed for all students. An increase in the critical thinking skills was achieved by 52 students (22.6%), 102 students (44.4%) and 76 students (33.0%) with a high, medium, and low criteria, respectively. This was in line with the results reported earlier (Sumardiana et al., 2019). They reported that the STEM-PBL model could enhance the students'

critical thinking skills. The high number of students with high critical thinking skills was closely related to the implementation of ethno-STEM PBL. As mentioned earlier that the STEM education showed comprehensive characteristics, i.e. problem solving, critical analysis, and providing students with opportunities to practice their thinking skills. The implementation of STEM-PBL provided challenges and trained students to think critically, analytically, logically, and mathematically (Afriana et al., 2016). It was proven that this model showed a great effect on students' achievement (Han et al., 2016).

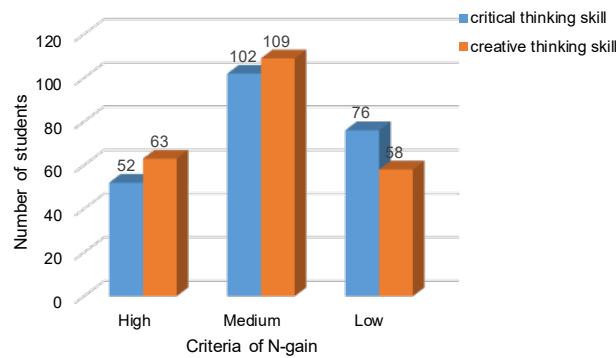


Figure 1. Frequency of Students' Critical and Creative Thinking Skills on the Three CCTS Criteria

The critical thinking skills investigated in this study were based on four indicators i.e. providing simple explanations, building basic skills, making inferences, and making advanced explanations.

The average score of pretest, posttest, and N-gain (%) of students in each critical thinking indicator is presented in Figure 2.

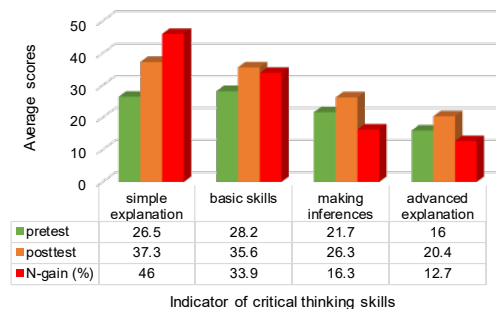


Figure 2. The Average Scores of Pretest, Posttest, and N-gain (%) for Each Indicator of Critical Thinking Skills.

An increase in the N-gain with low and medium criteria for the four critical thinking indicators was observed as is shown in Figure 2. Most of the improvement in the students' critical thinking was with an N-gain in the medium criteria. The N-gain in the medium category was achieved by students on two indicators i.e. simple explanation and building basic skills, while N-gain in the low criteria was achieved in the indicators of making inference and advanced explanation. This result was in line with that previously re-

ported (Han et al., 2016). It showed that a higher score was achieved by students when STEM PBL was used in comparison with non-STEM PBL. It was also reported that the integration of the ethnosience approach in the used learning models could improve the students' critical thinking (Arfianawati et al., 2016). It indicated that the high achievement of this indicator was very possible because the implemented ethno-STEM PBL could provide the students with guidance in linking the learned concepts with the existing

technology in their daily lives. This linkage could refer especially to the concepts related to traditional technology and well-developed techniques. These direct activities and field context were the main reasons for positive effects for the students with a level of knowledge.

Each indicator of critical thinking skills measured through question items at levels of C3, C4, and C5. The indicators have provided a simple explanation measured through question items related to the culture of the coloring process of *dawet ireng* using *londo merang* in explaining the concept of the colloidal system. Most of the students have been able to determine the dispersed phase and the dispersing medium. "Damen" (stems of rice plants that have been burned, immersed in water, filtrated) was used as a black coloring agent in the process of coloring *dawet ireng*. This indicated that the *dawet ireng* dye was a sol colloidal system with carbon and liquid as a dispersed phase and a dispersing medium, respectively.

The indicator of basic skills was measured through the question items related to the community culture in the production of soybean tofu. In that process, clumping of soybean juice was carried out by adding an acid or a salt compound. The process of tofu production was based on the concept of colloidal properties. Colloids are easily coagulated when reacting with an electrolyte solution. Acid and salt solutions are electrolyte solutions. Therefore, the process of tofu clumping could be done with the addition of vinegar, calcium sulfate, whey (tofu residual liquid), or seawater extract. This extract mainly contains calcium sulfate, potassium sulfate, calcium carbonate, and magnesium bromide.

An increase in the students' ability to make inferences was in the low criteria. However, this was higher than that to give an advanced explanation. This was possibly because the students have been accustomed to make conclusions or summaries at the end of each learning or experiment during the ethno-STEM PBL teaching/learning process. As a result, they have experienced in making inferences despite its low criteria. The question items related to the local culture of the process of making Soka roof tiles and the process of removing crust in the kettles with lime juice were used to measure the indicator of making inferences. The students were asked to evaluate the provided data before the concluding step.

The indicator of making an advanced explanation was that with the lowest increase in the N-gain among the four indicators. This was possibly due to the complex requirements of the

indicator such as more complex thinking, a more detailed explanation related to the occurring phenomenon. The learned concepts were not the only requirement to answer the questions. The students needed to interpret, analyze, evaluate, conclude and explain in answering them (Hughes & Lavery, 2015). Also, the students needed to link e.g. science, technology, and mathematics in the STEM-based learning. The ability of complex thinking also required the students to be able to see and interpret a certain problem comprehensively. They should not focus only on the element of cause and effect. These might be the reasons for the low level of achievement of this indicator. This result was supported by Johnson (2014) that someone will show high critical thinking if he/she could express his/her opinion confidently and produce ideas based on logical reasons. The questions about the role of the emulgator associated with the culture of the process of washing oily dishes using rubbing ash were used to correlate this indicator. The answer of many students was incomplete. Moreover, some students answered that the mixture of water and oil was an example of a colloidal system. Some students did not write typical reasons in their answers indicating the level of students' conceptual understanding.

The students' creative thinking skills are also presented in Figure 1. The frequency of students with increased creative thinking skills in terms of the N-gain value was 63 students (27.4%), 109 students (47.4%), and 58 students (25.2%) for high, medium and low criteria, respectively. It was reported that the average achievement of students' creative thinking skills after the implementation of STEM PBL was significantly different from that before the implementation of the learning model (Furi et al., 2018). A similar result was found in this study. Surprisingly, the students' creative thinking skills after the implementation of STEM PBL in this study were all in the high and medium criteria; none was in the low criteria. Likewise, it was previously reported that PBL STEM showed a big effect on increasing the creative thinking skills of students with high criteria (N-gain of 0.783) with an effect size of 0.98 (Furi et al., 2018).

The N-gain value in this study showed that all aspects of students' creative thinking skills increased after the implementation of STEM PBL, as presented in Figure 3. An increase in the criteria of all indicators of creative thinking skills in the medium and low criteria after the implementation of the STEM PBL was observed. This indicated that the STEM PBL has facilitated students to improve their creative thinking skills.

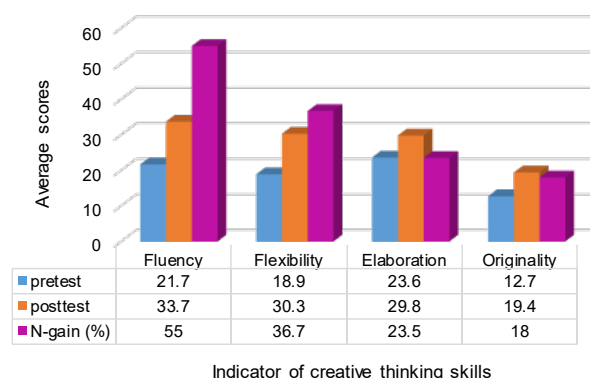


Figure 3. Average Scores of Pretest, Posttest, and N-gain (%) for Each Indicator of Creative Thinking Skills.

The students achieved the highest score in solving the fluency-type problems based on the results of normalized gain calculation indicating the highest increase. This result was indicated by the answers related to how to analyze and interpret the solutions based on mathematical data calculations. The achievement of this indicator was possibly due to their ability to answer questions coherently, systematically and do the calculations correctly. This finding was following that reported by Han et al. (2014) that the STEM PBL was an appropriate learning approach to improve students' mathematical grades. The difficulties in learning concepts related to mathematics could occur at almost every stage/level during the school years of students, even in adults. The problems representing this indicator have linked the concept of solubility of salts to the culture in eliminating water hardness and removing the crust formed in the isolated flask. The students were required to analyze and interpret the solutions based on the mathematical data calculations in comparing the solubility of hard soluble salts such as CaSO_4 , MgSO_4 , MgCO_3 , and CaCO_3 . The provided questions were in C4 cognitive levels. The students were required to have a good understanding of the prerequisite topics, i.e. chemical equilibrium and stoichiometry of reactions. Moreover, they were also required to master mathematical calculation methods. Mastering the mathematical concepts generally is needed to be able to understand and solve problems in Chemistry.

The originality aspect showed the lowest increase in N-gain. Most students found it difficult to solve the problems that required original solutions. This was possibly due to their struggles in memorizing the concepts. This resulted in a low level of innovation and imagination in creating a new idea. Only a few students provided the answers by mentioning expected ideas, despite

the lack of a complete and clear explanation. The question items with a C6 level were used to reveal the students' original thinking skills. The students were required to express creative ideas to accelerate the solubility of a certain salt. The low score of most students in answering questions was possibly due to their failure to describe ideas clearly and completely. They tended to provide answers as is commonly explained during class.

The N-gain of the flexibility aspect was not much different from that of the elaboration aspect. However, the flexibility aspect was improved to the medium criteria, while the elaboration aspect was to the low criteria. This indicated that providing challenges at each step of STEM PBL could motivate the students to find the information/processes in real-life supporting those obtained from the school. The students have begun to show their flexibility and elaboration abilities by thinking flexibly and broadly in giving arguments. The test results on this indicator showed that the students have been able to link information/processes in real life with those obtained from the school by providing various possible answers. The problems used for this indicator were related to the chemical processes that occur in the formation of stalactites/stalagmites and the culture of traditional salt-making in Bledug Kuwu. These problems were at the C5 level. The students were required to elaborate by evaluating the processes of the formation of stalagmites and stalactites from the phenomena presented in the problems. The students' answers showed that they were able to link one information with those from different disciplines, both in the phenomenon of the formation of stalactites/stalagmites and in the manufacture of Bledug Kuwu salt. These results were in line with what previously reported (Chonkaew et al., 2016) which stated that real-life based learning activities could help the students to realize the importance of theories and science

in the natural resource management. The STEM PBL learning was an appropriate learning model to help the students to develop flexibility in thinking. This proved that the students' creative thinking activities and abilities would be higher when they carried out the discussions or experiments in groups in comparison with receiving information/concepts from the teacher (as a typical lecture method).

In the elaboration aspect, the students were able to solve problems containing limited information by practicing the concepts of science during the learning. This achievement was most likely the result of a STEM-related chemistry learning experience. This learning could help the students to actualize their understanding of chemistry content. The students were required to determine the K_{sp} of $Mg(OH)_2$ and $Al(OH)_3$ as the problems in this indicator. The factor influencing the results of this skill was the students' ability to write the equilibrium reactions and have their phases correctly. Chemistry topics would be more easily understood by the students if the learning activities were associated with real-world situations. The students' curiosity would develop resulting in an increase in the skills in analyzing in their daily lives.

This study has shown that critical and creative thinking was how actual learning took place. This was following that previously reported that the STEM PBL could improve knowledge acquisition, help students to apply the knowledge to solve problems and actualize the scientific literacy competencies and creativity (Permanasari, 2016). When the strategies for critical and creative thinking were linked to appropriate learning goals, the corresponding learning experiences would become more meaningful, challenging and interesting. Engaging the students with a variety of critical and creative thinking strategies that have been applied to an appropriate curriculum content would encourage them to think more diverse and meaningful about the content. Familiarizing the students would help them to be well-prepared in finding the problems and develop solutions with innovative products. Moreover, they would be more confident in communicating the results and ideas to others.

The level of achievement of students' critical and creative thinking skills in the medium and low criteria in this study indicated that the implementation of the ethno-STEM PBL could actualize students to foster critical and creative thinking skills. The ethno-STEM PBL helped students not only memorize the concepts but also how they understand the science concepts and

their relationship to technology, engineering, and mathematics. They also related the concepts to the applications in daily life, especially in various elements of the culture that could survive until now (Kun, 2013). The level of achievement of students' critical and creative thinking was also supported by the presence of challenges in solving the problems through project assignments. In PBL, the students would collaboratively try to arrange their knowledge in solving the problems and trying various solutions that encourage critical and creative thinking (Darling-Hammond et al., 2019).

The successful implementation of the ethno-STEM PBL was inseparable from the learning process. The problems raised in the PBL were semi-open problems, which means the answer to the problem was uncertain (Adamuti-Trache & Sweet, 2014). The ethno-STEM PBL allowed the students to develop possible answers by collecting and analyzing data to solve the problems. The students were happy to be involved in doing real activities. They were also happy to directly observe traditional processes during the teaching/learning process. As a learning model that challenged the students to learn and work together with their groups to find solutions to real problems (Laboy-Rush, 2011), the project assignments given to the students have stimulated them to understand the concepts being learned in creating products (Sumarni et al., 2016). This proved that the ethno-STEM PBL was an innovative learning approach to improve the students' problem-solving skills. This approach required collaboration, peer communication, and independent learning.

However, behind the successful implementation of the ethno-STEM PBL in improving the students' critical and creative thinking skills in this study, the students with a low level of creative and critical thinking skills were still observed. Most students did not have any idea about what they will observe. As a result, they still find difficulties in co-relating what being observed and what is studied. Another problem was that the students were somewhat not familiar with "why" questions. This made them missed the opportunity of developing their thinking skills in explaining a problem. This might be due to the students' inability such as not yet accustomed to student-centered learning, different questions from usual, lack of understanding of the prerequisite materials, lack of creativity, and students' activity and involvement in the learning process. This was reinforced by the Trend International Mathematics and Science Study (TIMSS) which stated that the students' level of creative thinking

skills in Indonesia was relatively low because the students were not accustomed to working on high and advanced category questions that required high-level thinking skills in solving them. This, of course, would be one of the challenges faced by the teachers in improving the students' performance in the STEM field.

The effectiveness of the implementation of the ethno-STEM PBL in improving the students' critical and creative thinking was not as expected as previously mentioned. However, this study has provided insight into the implementation of the ethno-STEM PBL activities in schools as an effort to improve the students' critical and creative thinking skills. This finding was expected to help the teachers to rethink how the students benefit from their involvement in the ethno-STEM PBL activities and restructure their teaching strategies to achieve student-centered learning.

CONCLUSION

This study showed that the ethno-STEM PBL could improve the average critical and creative thinking skills of students in all indicators in a variety of categories from low to medium criteria. Both the "advanced explanation" aspect of critical thinking indicators and the "originality" aspect of creative thinking indicators showed the lowest results. Despite showing flexible thinking, the students' critical and creative thinking skills were at the stage of giving simple explanations.

Several impacts of the implemented ethno-STEM PBL in this study were highlighted. This study indicated that continuous implementation of critical and creative thinking strategies could develop more meaningful concepts as well as high-level thinking skills. The implementation of the ethno-STEM PBL in this study has improved the students' abilities in thinking skills such as cause-effect thinking, predicting reasonable results, analyzing data through various points of view, evaluating, and creating. Those skills were developed through frequent opportunities to explore and express opinions and ideas in critical, receptive, collaborative and creative thinking.

An analysis of how the link between the students' critical thinking abilities and their creative thinking abilities would be part of our future work. This would cover the clarification on the reasons for the results obtained, e.g. investigating whether the students with different performance levels show different levels of thinking growth and how individual factors of students function with the various ethno-STEM PBL components. Additional data would be needed to reveal the ef-

fectiveness of the ethno-STEM PBL and further investigate how and why the ethno-STEM PBL could positively enhance the students' critical and creative thinking skills. Incorporating effective critical and creative thinking strategies precisely in the teaching contents would be necessary. The thinking skills taught in relevant content would promote the development of the students' thinking skills into critical and creative thinking habits, while playing with ideas and processing the content information in various ways. The students would feel joy in the learning, find meaning and personal relevance in the learning.

REFERENCES

- Adamuti-Trache, M., & Sweet, R. (2014). Science, technology, engineering and math readiness: ethno-linguistic and gender differences in high-school course selection patterns. *International Journal of Science Education*, 36(4), 610-634.
- Afriana, J., Permanasari, A., & Fitriani, A. (2016). Penerapan project-based learning terintegrasi STEM untuk meningkatkan literasi sains siswa ditinjau dari gender. *Jurnal Inovasi Pendidikan IPA*, 2(2), 202-212.
- Arfianawati, S., Sudarmin, M., & Sumarni, W. (2016). Model pembelajaran kimia berbasis etnosains untuk meningkatkan kemampuan berpikir kritis siswa. *Jurnal Pengajaran MIPA*, 21(1), 46-51.
- Bronson, P., & Merryman, A. (2010). The creativity crisis. *Newsweek*, 10 July.
- Chonkaew, P., Sukhummek, B., & Faikhamta, C. (2016). Development of analytical thinking ability and attitudes towards science learning of grade-11 students through science technology engineering and mathematics (STEM education) in the study of stoichiometry. *Chemistry Education Research and Practice*, 17(4), 842-861.
- Coşkun, Y. (2018). A study on metacognitive thinking skills of university students. *Journal of Education and Training Studies*, 6(3), 38-46.
- Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2019). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, 1-44.
- Dwyer, C. P., Hogan, M. J., & Stewart, I. (2014). An integrated critical thinking framework for the 21st century. *Thinking Skills and Creativity*, 12, 43-52.
- Fields, Z., & Bisschoff, C. A. (2014). Developing and assessing a tool to measure the creativity of university students. *Journal of Social Sciences*, 38(1), 23-31.
- Furi, L. M. I., Handayani, S., & Maharani, S. (2018). Eksperimen model pembelajaran project-based learning dan project-based learning terintegrasi stem untuk meningkatkan hasil belajar dan kreativitas siswa pada kompetensi dasar

- teknologi pengolahan susu. *Jurnal Penelitian Pendidikan*, 35(1), 49-60.
- Gelerstein, D., Del Rio, R., Nussbaum, M., Chiuminatto, P., & López, X. (2016). Designing and implementing a test for measuring critical thinking in primary school. *Thinking Skills and Creativity*, 20, 40-49.
- Han, S., Capraro, R., & Capraro, M. M. (2014). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: the impact of student factors on achievement. *International Journal of Science and Mathematics Education*, 13(5), 1089-1113.
- Han, S., Rosli, R., Capraro, M. M., & Capraro, R. M. (2016). The effect of science, technology, engineering and mathematics (STEM) project-based learning (PBL) on students' achievement in four mathematics topics. *Journal of Turkish Science Education*, 13(special), 3-29.
- Hughes, W., & Lavery, J. (2015). *Critical Thinking: An Introduction to the Basic Skills-Canadian Seventh Edition*. Broadview Press.
- Johnson, E. B. (2014). CTL Contextual Teaching & Learning. *Bandung: Kaifa*.
- Kun, P. Z. (2013, September). Pembelajaran sains berbasis kearifan lokal. In *PROSIDING: Seminar Nasional Fisika Dan Pendidikan Fisika* (Vol. 4, No. 1).
- Liliawati, W., Rusnayati, H., & Aristantia, G. (2018, January). Implementation of STEAM education to improve mastery concept. In *IOP Conference Series: Materials Science and Engineering* (Vol. 288, No. 1, p. 012148). IOP Publishing.
- Mutakinati, L., Anwari, I., & Kumano, Y. (2018). Analysis of students' critical thinking skill of middle school through stem education project-based learning. *Jurnal Pendidikan IPA Indonesia*, 7(1), 54-65.
- Nakano, T. D. C., & Wechsler, S. M. (2018). Creativity and innovation: Skills for the 21st Century. *Estudos de Psicologia (Campinas)*, 35(3), 237-246.
- Permanasari, A. (2016). STEM education: Inovasi dalam pembelajaran sains. In *Prosiding SNPS (Seminar Nasional Pendidikan Sains)* (Vol. 3, pp. 23-34).
- Rahmawati, Y., Ridwan, A., & Hadinugrahaningsih, T. (2019, January). Developing critical and creative thinking skills through STEAM integration in chemistry learning. In *Journal of Physics: Conference Series* (Vol. 1156, No. 1, p. 012033). IOP Publishing.
- Retnawati, H., Djidu, H., Apino, E., & Anazifa, R. D. (2018). Teachers' knowledge about higher-order thinking skills and its learning strategy. *Problems of Education in the 21st Century*, 76(2), 215-230.
- Laboy-Rush, D. (2011). Integrated STEM education through project-based learning. *Portland, United States of America: Sematintinscholar.org*.
- Saido, G. M., Siraj, S., Bin Nordin, A. B., & Al Amedy, O. S. (2015). Higher Order Thinking Skills among Secondary School Students in Science Learning. *Malaysian Online Journal of Educational Sciences*, 3(3), 13-20.
- Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, 4(1), 13.
- Sudarmin, S., Sumarni, W., Endang, P. R. S., & Susilogati, S. S. (2019, October). Implementing the model of project-based learning: integrated with ethno-STEM to develop students' entrepreneurial characters. In *Journal of Physics: Conference Series* (Vol. 1317, No. 1, p. 012145). IOP Publishing.
- Sumardiana, S., Hidayat, A., & Parno, P. (2019). Kemampuan berpikir kritis pada model project-based learning disertai STEM siswa SMA pada suhu dan kalor. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, 4(7), 874-879.
- Sumarni, W., Wardani, S., Sudarmin, S., & Gupitasari, D. N. (2016). Project-based learning (PBL) to improve psychomotoric skills: a classroom action research. *Jurnal Pendidikan IPA Indonesia*, 5(2), 157-163.
- Sumarni, W., Supardi, K. I., & Widiarti, N. (2018, April). Development of assessment instruments to measure critical thinking skills. In *IOP Conference Series: Materials Science and Engineering* (Vol. 349, No. 1, p. 012066). IOP Publishing.
- Sumarni, W., Wijayati, N., & Supanti, S. (2019). Kemampuan kognitif dan berpikir kreatif siswa melalui pembelajaran berbasis proyek berpendekatan STEM. *Jurnal Pembelajaran Kimia OJS*, 4(1), 18-30.
- Uziak, J. (2016). A project-based learning approach in an engineering curriculum. *Global Journal of Engineering Education*, 18(2), 119-123.
- Ventista, O. M. (2018). Multi-trait multi-method matrices for the validation of creativity and critical thinking assessments for secondary school students in England and Greece. *International Journal of Assessment Tools in Education*, 5(1), 15-32.
- Wardani, S., Lindawati, L., & Kusuma, S. B. W. (2017). The development of inquiry by using Android-system-based chemistry board game to improve learning outcome and critical thinking ability. *Jurnal Pendidikan IPA Indonesia*, 6(2), 196-205.
- Weisberg, R. W. (2015). On the usefulness of "value" in the definition of creativity. *Creativity Research Journal*, 27(2), 111-124.
- Wijayati, N., Sumarni, W., & Supanti, S. (2019). Improving student creative thinking skills through project-based learning. *KnE Social Sciences*, 408-421.
- Yoon, C. H. (2017). A validation study of the Torrance tests of creative thinking with a sample of Korean elementary school students. *Thinking Skills and Creativity*, 26, 38-50.