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Effectiveness of STEAM-based blended learning on students' critical and creative thinking skills

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ABSTRACT

The critical and creative thinking skills of Indonesian students are relatively low from countries in the Malay family such as Malaysia and Singapore. This research aims to improve students' critical and creative thinking skills through the use of Science, Technology, Engineering, Art, Mathematics (STEAM) based blended learning. This research is a quasi-experimental study using a nonequivalent pretest-posttest control-group design. The sample consists of 180 junior high school students in Yogyakarta, Indonesia. The samples in this study are 90 experimental class students and 90 control class students selected by random sampling cluster techniques because the selected samples come from individual groups or clusters. The instrument in this study consists of six questions in the form of essay questions. Test questions are analyzed using the gain score test and Kruskal-Wallis with SPSS 22. The results show steam-based blended learning can improve critical and creative thinking skills on all indicators with medium to high categories. The improvement of students' critical and creative thinking skills in experimental classes is higher than that of the control class. In addition, there are differences in learning outcomes between control classes and experimental classes. STEAM-based blended learning can be an alternative for teachers to solve the problem of low critical and creative thinking skills.

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1. INTRODUCTION

The 21st century is characterized by the rapid development of science and technology, globalization, and economic growth. Education needs to prepare students to face global challenges, social realities, and future work [1]. Quality education can stimulate students in developing thinking skills [2]. Thinking activities in the learning process will form a mindset that becomes the main purpose of learning as well as useful in the future [3]. An important thinking skill developed by students to meet skills in the 21st century is critical and creative thinking skills [4]. Critical and creative thinking skills are key to overall cognitive and intellectual development [5]. Critical and creative thinking skills required students to solve problems and decisions making in their lives [6].

Critical thinking skills will help students to think rationally [7], develop analytical skills, decision-making skills when facing multiple options [8], connect and evaluate all aspects of the problem comprehensively [9]. Results of critical thinking skills research in some areas in Indonesia such as East Java [10], Yogyakarta [11], and Central Java [12] still relatively low. The phenomenon is observed not only in Indonesia but also in other countries such as California. According to Halpern *et al*. [13], students' critical thinking skills in southern California are relatively low. The cause of low critical thinking skills is that learning has not facilitated students to practice critical thinking [14] and the learning model used by teachers has not been able to involve active students in learning [15]. In addition to equipping students with critical thinking skills, the learning process also needs to develop creative thinking skills.

Creative and critical thinking complete to each other and production of qualified innovations and sustainability of education. Creative thinking skills are considered an integral part of 21st century skills that need to be emphasized in the science education curriculum [16]. Creative thinking includes divergent thinking that leads to more than one solution to a problem [17]. Creative thinking skills train students to develop new ideas, synthesize ideas, be open with different responses and perspectives, and determine the effectiveness of ideas [18]. Creative thinking is not a fixed characteristic that a person has or does not have, so creative thinking can be taught and developed in a person [1]. The results of creative thinking skills research in several regions in Indonesia such as Riau [19], Surakarta [20], Klaten [21], and Boyolali [22] are still relatively low. The phenomenon is observed not only in Indonesia but also in other countries such as Oman. Al-Abdali and Al-Balushi [23] showed that science teachers in Oman tend to focus on preparing for students' exams, thus neglecting to practice creative thinking skills.

Critical and creative thinking skills will develop well if teachers facilitate and encourage the thinking potential of students [24]. However, critical, and creative thinking skills have not been optimal and are a priority taught in schools. A mini study of 21st century skills in Asia and Africa by the Global Partnership for Education [25] shows there is a need to generate and share knowledge of how 21st century skills are integrated into the curriculum. Education to develop 21st century skills offers a new way to frame cross-disciplinary learning [26]. Science, Technology, Engineering, Art, Mathematics (STEAM) offers cross-disciplinary learning that explores students' various lateral and creative ways of thinking [26]. STEAM supports the transition of traditional lecture-based teaching to inquiry and project teaching [27]. STEAM incorporates elements of art in STEAM learning to enhance creativity, innovation, problem-solving skills, and encourage the active involvement of students [28]. STEAM also increases motivation, encourages critical thinking, and makes science learning more interesting [29]. STEAM can be an alternative solution to improve students' critical and creative thinking skills.

Science learning needs to be directed to utilize technology, especially in the pandemic COVID-19 situation that requires students to learn from home. Indonesia's Minister of Education and Culture requested that the learning process be diverted online from home. Wang *et al*. [30] revealed that the use of technology in learning becomes a challenge for teachers. Ghavifekr and Rosdy [31] explained that the learning process needs to integrate technology to be more effective, efficient, and attract students' learning interests. According to Han and Ellis [32], learning activities can be done by combining traditional and online called blended learning. Klentien and Wannasawade [33] explains that blended learning combines the advantages of direct and online learning. Another opinion was expressed by Clement, Vandeput, and Osaer [34] stated that blended learning is known as learning that combines modern and conventional learning using a scientific approach. Blended learning is useful to facilitate variations in learning styles, enrich learning experiences, maintain consistency of learning topics, and improve the quality of learning [35]. Blended learning is effective for improving discussion and search for information outside the classroom [36]. Students who follow blended learning have better learning achievements than students who follow traditional learning [37]. Another study by Kazu and Demirkol [38] found that students who used blended learning had higher posttest averages than students using traditional learning.

Students' critical and creative thinking skills are still relatively low. The integration of the STEAM approach with blended learning is done to condition learner-centered learning through online and offline learning to improve critical and creative thinking skills. Previous research has shown that the application of blended learning in 21st century learning creates better practices for teaching science, technology, engineering, art, and mathematics [39]. STEAM in blended learning improves learning motivation, develops high-level thinking skills, and creates meaningful learning [40]. However, the influence of STEAM-based blended learning in science learning related to the development of students' critical and creative thinking skills has not been well reported.

Based on these problems, the research question are: i) How to improve critical thinking skills through the use of STEAM-based blended learning?; and ii) How to improve creative thinking skills through the use of STEAM-based blended learning? This research focuses on the influence of STEAM-based blended learning on critical and creative thinking skills that aim: i) Improve critical thinking skills using STEAM-based blended learning; and ii) Improve creative thinking skills using STEAM-based blended learning.

2. RESEARCH METHOD

This research is quasi-experimental. It was chosen because the external factors that influenced the results of the study could not be fully controlled. The research design used is a nonequivalent pretest-posttest control-group design presented in Table 1.

Table 1. Nonequivalent pretest-posttest control-group design

Group	Pretest	Treatment	Posttest
Experiment class	P1	T1	P3
Control class	P2	T2	P4

P1=pretest experimental classes; P2=control classes; P3=posttest of experiment classes; P4=control classes

The research begins by providing pretest experimental classes (P1) and control classes (P2). Experimental classes use STEAM-based blended learning (T1), while control classes use conventional learning (T2). The research ended by providing a posttest of experiment classes (P3) and control classes (P4). The subject of the study was a junior high school student in Yogyakarta. Sampling techniques use random sampling clusters because the selected samples come from individual groups or clusters. The sample consisted of 180 grade VII students aged 12-13 years with 81 males and 99 females. Instruments used in the form of tests and non-tests. The test instrument is a test of critical and creative thinking skills. The test question is an open question. Brookhart [41] explained that open questions are chosen because they can encourage effective and efficient thinking in directing to high-level thinking skills. All question items are analyzed for validity and reliability. The validity of the question uses quests, while the reliability of the problem uses Cronbach Alpha.

The data collection procedure starts from preliminary observation and literature study. Observations are made to find problems in learning and literature studies to look for theories of existing problems. Classes are divided into experiment classes and control classes. The experimental class uses STEAM-based blended learning, while the control class uses conventional models with a scientific approach. Learning starts with pretesting the entire class. Learning ends with post-testing after the whole series of learning has been completed. The improvement of critical and creative thinking skills was analyzed using the gain score equation according to Hake [42] as shown in (1). Criteria for gain score are presented in Table 2.

$$N - gain = \frac{\%\,posttest\ score - \%\,pretest\ score}{maximum\ score - \%\,pretest\ score} \quad (1)$$

Table 2. Criteria for improving critical and creative thinking skills

Gain score	Criteria
g≥0.70	High
0.30≤g≤0.70	Medium
g<0.30	Low

Further analysis to determine whether there is a difference in learning to the score of students using the Kruskal-Wallis test with SPSS 22. This test is used because the distribution of variables tested does not have to be normal. The hypotheses in the study are: i) H_1: There are differences in learning models for critical thinking skills; and ii) H_2: There are differences in learning models for creative thinking skills. The criteria for acceptance and rejection of hypotheses H_1 and H_2 are accepted if Asymp Sig<α with α (0.05).

3. RESULTS AND DISCUSSION

3.1. Validity and reliability of instruments

The critical and creative thinking skills that will be used are analyzed for the validity and reliability of the problem. The validity of the question is analyzed using the quest program, while the reliability of the problem uses Cronbach Alpha with the help of SPSS 22. The validity of critical and creative thinking skills is presented in Table 3.

Table 3. Validity of critical and creative thinking skills

Variable	Item number	INFIT MNSQ	Description
Critical thinking skills	Item 1	0.96	Fit
	Item 2	0.97	Fit
	Item 3	0.82	Fit
Creative thinking skills	Item 4	1.18	Fit
	Item 5	1.06	Fit
	Item 6	0.83	Fit

Table 3 shows that all question items are declared fit. The determination of fit tests refers to Adams and Khoo [43] based on the average infit value of Infit MNSQ in the range of 0.77 to 1.30. The Reliability instrument used in this study used Cronbach Alpha with an alpha value of 0.81 which indicates a reliable instrument with an excellent category. Determination of instrument reliability refers to Guilford [44] consisting of 0.00 (invalid), 0.00-0.20 (bad), 0.20-0.0 40 (less), 0.40-0.60 (enough), 0.60-0.80 (good), and 0.80-1.00 (very good). All points of the question can be declared valid and reliable to assess critical and creative thinking skills.

3.2. Critical thinking skills

Improved critical thinking skills are analyzed with N-gain. The results obtained for critical thinking skills before and after learning between conventional learning classes (control classes) and STEAM-based blended learning (experimental classes) are presented in Table 4. The table shows that in general critical thinking skills are improving. However, the N-gain value in the experiment class is higher than in the control class. In the experimental class, the indicator describes gaining N-gain of 0.73 (high category), evaluating indicator obtaining N-gain of 0.69 (moderate category), indicator concludes obtaining N-gain of 0.79 (high category). In the control class, the indicator describes gaining N-gain of 0.29 (low category), evaluating indicator obtaining N-gain of 0.20 (low category), indicator concludes obtaining N-gain of 0.27 (low category).

Table 4. Score any critical thinking skills indicator

Class	Explain			Evaluate			Conclude		
	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain
Experiment	5	16	0.73	4	15	0.69	6	17	0.79
Control	6	10	0.29	5	8	0.20	5	9	0.27

To find out whether there is a difference in critical thinking skills between experimental and control classes conducted Kruskal-Wallis test with SPSS 22. Kruskal-Wallis test results critical thinking skills are presented in Table 5. The table shows that aspects of critical thinking skills were obtained by Asymp. Sig. (0.000)<α(0.05), so it can be explained that there are differences in critical thinking skills between students who carry out learning with steam-based blended learning and conventional learning.

Table 5. Kruskal-Wallis test results test critical thinking skills

Aspects	Chi-Square	df	Asymp. Sig.
Critical thinking skills	137.390	1	0.000

3.3. Creative thinking skills

Improved creative thinking skills analyzed with N-gain Results obtained for creative thinking skills before and after learning between conventional learning classes (control classes) and STEAM-based blended learning (experimental classes) are presented in Table 6. The table shows that in general creative thinking skills are improving. However, the N-gain value in the experiment class is higher than in the control class.

In the experimental class, the fluency indicator gained an N-gain of 0.76 (high category), flexibility indicator obtained N-gain of 0.86 (high category), and the originality indicator gained N-gain of 0.60 with medium category. In the control class, the fluency indicator obtains N-gain of 0.21 (low category), the flexibility indicator obtains N-gain of 0.15 (low category), and the originality indicator obtains N-gain of 0.29 (low category).

Table 6. Score any indicator of creative thinking skills

Class	Fluency			Flexibility			Originality		
	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain
Experiment	7	17	0.76	6	18	0.86	5	14	0.60
Control	6	9	0.21	7	9	0.15	6	10	0.29

To find out whether there is a difference in critical thinking skills between experimental and control classes conducted Kruskal-Wallis test with SPSS 22. Kruskal-Wallis test results of critical thinking skills are presented in Table 7. The table shows that creative thinking skills were gained by Asymp. Sig. (0.000)<α (0.05), so it can be explained that there are differences in creative thinking skills between students who carry out learning with steam-based blended learning and conventional learning. The results of the N-gain analysis showed critical thinking skills in all aspects improved with the improvement of classes that carried out steam-based blended learning (experimental classes) higher than classes that carried out conventional learning (control classes). The increase in students in making conclusions is highest compared to other indicators. That is because students are used to making conclusions at the end of each lesson. As a result, they have experienced making conclusions. The increase in the ability to evaluate is relatively moderate with the lowest N-gain increase among the three indicators. The ability to evaluate involves complex thinking, not just answering questions. Students need to assess ideas based on certain criteria [45] and make decisions based on valid information [46]. Students are asked to evaluate the information provided in the question. Some students write answers briefly without the typical reason for the answer. Kopzhassarova *et al*. [47] explained that a good critical thinker can express his ideas with confidence along with logical reasons.

Table 7. Kruskal-Wallis test results test creative thinking skills

Aspects	Chi-Square	df	Asymp. Sig.
Creative thinking skills	136.368	1	0.000

The results of the Kruskal-Wallis test show that there are differences in critical thinking skills between students who carry out learning with STEAM-based blended learning and conventional learning. The results showed that STEAM-based blended learning was able to improve students' critical thinking skills. This research is in line with research that shows that critical thinking can develop through a learning environment that supports thinking activities [48]. STEAM-based blended learning can provide interesting science learning, improve active and meaningful learning, stimulate the improvement of critical thinking skills of students [29]. Creative thinking skills on all indicators have increased, the class that implements STEAM-based blended learning (experimental class) has a higher increase than the class that carries out conventional learning (control class). Flexibility has the highest increase compared to other indicators. Students can produce varied answers and see information from various points of view. According to Simonton [49], creative thinking can express different ideas flexibly in solving problems and producing a product that is different from existing ones. The increase in the originality indicator is classified as moderate with the lowest N-gain increase among other indicators. Students have difficulty creating unique new ideas with their thoughts. They are used to memorizing concepts, so tend to answer questions according to what they get in class.

Runco and Jaeger [50] explained that the main requirement of creative thinkers when able to produce ideas that have originality. This opinion is reinforced by Dumas and Dunbar [51] creative thinkers can express new ideas, unique, even unusual. In addition, there are differences in creative thinking skills between students who carry out learning with steam-based blended learning and conventional learning. It shows that STEAM-based blended learning can improve students' creative thinking skills. STEAM-based blended learning can train students to be like scientists who have creative thinking skills in solving complex problems [29], the art element in STEAM is considered able to increase creativity, innovation, problem-solving skills, as well as encourage the active involvement of students [28]. STEAM-based blended learning can improve students' critical and creative thinking skills better than conventional learning. Baepler, Walker, and Driessen [52] revealed that students in conventional learning classes tend to be passive for a long time. STEAM-based blended learning provides a different context of face-to-face learning than traditional learning. Learning is conducted online and face-to-face.

Online learning activities are conducted before face-to-face learning. Sevima Edlink is used for online activities. The topic of science is the classification of matter. Topics are presented by utilizing used and recycled materials. On the Sevima Edlink page the teacher uploads worksheets and references related to the topic. Students use references and other learning resources from the internet to help complete each activity in a worksheet. Teachers emphasize student engagement through discussion forums by encouraging students to participate in discussions. Students discuss topics presented in worksheets. They are trained to understand concepts connected to technology, engineering, art, and mathematics associated with applications in life. student's upload completed worksheets in an Sevima Edlink. Teachers review and evaluate before face-to-face meetings. Manwaring *et al*. [53] explained that active learning individually or online groups in discussion activities can increase the emotional and cognitive involvement of students.

Teachers divide students into groups and ask students to prepare used materials and recycling materials for use during face-to-face learning. These materials are used to solve challenges related to science topics that teachers provide collaboratively with their groups. Challenges are given so that students can find solutions to real problems [54]. Students are also encouraged to understand the concepts learned by presenting the idea of product design of their thoughts [55]. Various problem-solving solution ideas and product design ideas are presented to other groups so that students can exchange ideas. The most interesting idea gets rewarded by the teacher. The implication is that students become more passionate, confident, and can inspire others. This proves that STEAM-based blended learning facilitates the improvement of critical and creative thinking skills. Combining online and face-to-face learning can expand student thinking, increase student engagement, and leverage technology as a learner-centered approach [56]. Student participation in learning with the teacher and student interaction provides emotional engagement [57] which is important in the academic performance of students [58].

4. CONCLUSION

The results showed that steam-based blended learning improves critical and creative thinking skills on all indicators with medium to high categories. The improvement of students' critical and creative thinking skills in experimental classes is higher than that of the control class. The results also showed that there are differences in learning outcomes between the control class and the experimental class this research implies that the reward for the best students makes them more excited, confident, and can inspire others. This study can contribute to the thinking that can be used by future researchers to improve the competence of the 21st century, especially in the study of science. Teachers, practitioners, and researchers can use and modify STEAM-based blended learning by adding relationship analysis of critical and creative thinking skills, adding interesting variations of learning models or media, and considering the components of online learning to facilitate communication between students, and teachers. In general, STEAM-based blended learning can contribute to the improvement of the 21st century skills. However, this study still has limitations in that respondents only come from one school, so the research does not reflect the results of various schools. Different schools can give different results.

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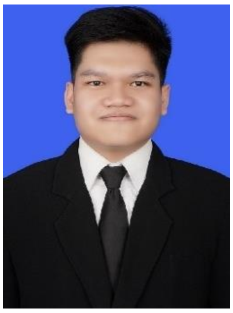

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