Biosfer: Jurnal Pendidikan Biologi

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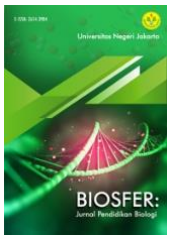

Integrating STEAM with PjBL and PBL on biology education: Improving students' cognitive learning results, creative thinking, and digital literacy

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ARTICLE INFO

Article history
Received: 12 December 2021
Revised: 15 February 2022
Accepted: 19 February 2022

Keywords:
Creative thinking
Digital literacy
Project based learning
Problem based learning
STEAM

ABSTRACT

STEAM (Science, Technology, Engineering, Art, and Mathematics) is an innovative interdisciplinary learning approach that can be integrated with PjBL and PBL learning models. This research investigates the effect of STEAM combined with PjBL and PBL learning models on the cognitive learning results, creative thinking skills and digital literacy of Class X senior high school students at SHS 3 Maluku Tengah and SHS 39 Salahutu. This research was conducted in the even semester of the 2020/2021 academic year. The research instruments included an essay test and digital literacy observation sheets. The research data were analyzed using inferential statistics (ANCOVA and ANOVA). The research results indicate that the integration of STEAM with PjBL and PBL learning models significantly affects students' cognitive learning results and creative thinking ($p<0.05$). However, the integration of STEAM and PjBL and PBL learning models does not significantly affect students' digital literacy ($p>0.05$). The integration of STEAM with PjBL and PBL learning models provides innovation in implementing the two learning models, which improves the learning steps and the learning process. The integration of STEAM with the PjBL learning model can be used to enhance cognitive learning outcomes and creative thinking skills for other biological concepts in senior high school level learning.

Hehakaya, W., Matdoan, M. N., & Rumahlatu, D. (2022). Integrating STEAM with PjBL and PBL on biology education: Improving students' cognitive learning results, creative thinking, and digital literacy. *Biosfer: Jurnal Pendidikan Biologi, 15*(1), 76-84. https://doi.org/10.21009/biosferjpb.24468

INTRODUCTION

One of the 21st century learning approaches which are associated with soft skills is STEAM (Science, Technology, Engineering, Art, and Mathematics). This is an innovative interdisciplinary learning approach, which integrates science, technology, engineering, art, and mathematics with the focus of solving real-life problems. In STEAM learning, the students are trained how the concepts and principals of science, technology, engineering, art, and mathematics can be combined to develop a certain product (Torlakson, 2014). In addition, STEAM is also transdisciplinary in that it does not merely focus on mathematics, science, or technology, but it also focuses on social life in a community (Guyotte et al., 2015). Boy (2013) explains that the STEAM approach is a humanistic design in that this approach improves not only technology, education system and practices, but also students' participation to act, express, criticize, explore concepts, and associate them with the complex system of life.

Biology learning in the 21st century requires students to develop creativity in learning and not only focus on mastering concepts. STEAM learning provides color in 21st century learning because it integrates elements of science, technology, engineering, art and mathematics as well as combines the five elements. The result is that STEAM learning can be combined with various types of learning models to increase students' creativity, train them to use technology and integrate engineering knowledge in learning, combine elements of art and mathematics to empower ways of thinking, logic and innovation. The implementation of STEAM in learning can alter the common educational paradigm between teachers and students (Herro & Quigley, 2016). Many studies on the integration of STEAM in learning model have been carried out. Rosikhoh et al. (2019) explained that teachers approved and accepted the implementation of STEAM in mathematics teaching and learning process although there has not been much supporting literature in learning. Therefore, research on the implantation of STEAM in Science learning, especially Biology, is necessary. STEAM is an integrated and thematic learning that can be used by biology teachers to study biology as a science from various perspectives, namely using internet technology to carry out scientific literacy; while engineering can be defined as the way students conduct scientific experiments or observations using problem solving techniques, using various experimental tools and materials, designing and creating experimental/observation stages that can be done to obtain data; art that aims to produce biological products by taking into account the shape, arrangement, neatness, and quality; the integration of mathematics in biology learning can be done by measuring, counting and adding up. Several researches have been conducted on the integration of STEAM in Biology learning. Utomo et al. (2020) integrated STEAM in flash animation-based Biotechnology module, and the results indicated that the N-gain score of the pretest and posttest was 0.72, which was categorized as high. Suciari et al. (2021) also explained that the integration of STEAM in PjBL learning had a positive effect on the students' concept gaining. Moreover, Retnowati et al. (2021) reported that a lesson plan integrated with STEAM based biology-entrepreneurship had fulfilled the validity criteria and had a significant effect on the students' critical thinking skills and entrepreneurship interest. Saidaturrahmi et al. (2021) integrate STEAM with PjBL which is able to improve the science competence of junior high school students in the experimental class compared to the control class.

Based on the results of those researches, it is known that STEAM approach can be integrated with several learning models, such as Problem Based Learning (PBL) and Project Based Learning (PjBL). The syntax of these two learning models can be equated, namely problem solving oriented. In addition, the syntax of these two models can be integrated with the meaning of the term STEAM in high school biology learning in Central Maluku. The difference between these two learning models is that the problem solving in the PjBL learning model is done through a series of projects to produce a product. Meanwhile, the problem solving in the PBL learning model is done through Non-Experiment Student worksheets. The research conducted by Sayuti et al. (2020) showed that the implementation of PjBL could improve students' creative thinking skills through group work to solve problems. Creative thinking can empower students creativity to find ideas for solving problems in various versions (Kutlu & Gökdere, 2015; Ulger, 2018). The implementation of PBL learning model also had an effect on students' creative thinking and cognitive learning results. Research by Leasa et al. (20121) recommends that learning using PBL in elementary schools can improve students' higher order thinking skills, while Anwar et al. (2021) explained that PBL learning accommodates students to be independent, construct their understanding through problem analysis activities, work together with groups and be able to communicate effectively and accurately. Lee and Therriault (2013) explained that creative thinking had a correlation with cognitive process, because producing creativity requires long-term memory. In the ere of 21st century learning, learning activities can be carried out using different learning models, however, the orientation of the learning should center on digital literacy. According to Buckingham (2016), digital media are necessary for learning sources. However, the digital media should be applied properly and accurately. These two learning models can be used and integrated with STEAM approach and applied in the learning process in Senior High Schools in Maluku Tengah.

The learning process in senior high school 3 Maluku Tengah and senior high school 39 Salahutu has already implemented student-centered cooperative learning models, one of which is PBL learning model. However, PjBL learning model and STEAM as a new learning approach in the 21st century have never been implemented and integrated. One of the challenges that should be done in these two schools is to implement the two learning models using STEAM approach. Therefore, the implementation of the learning models using STEAM approach should be able to empower students' creative thinking skills, concept gaining, and digital literacy.

METHODS

Research Design

This is a quasi-experimental research with Pretest-Posttest Nonequivalent Control Group Design (Table 1). The focus of this research is to analyze the effect of two learning models integrated with STEAM approach on cognitive learning results, creative thinking skills, and digital literacy of Class X at senior high school (SHS) 3 Maluku Tengah and SHS 39 Salahutu, Indoenesia.

Table 1
Research design

Pretest	Experimental Group	School	Class	Posttest
O1	PjBL integrated with STEAM	SHS 3 Maluku Tengah	X1	O2
		SHS 39 Salahutu	X1	
O3	PBL integrated with STEAM	SHS 3 Maluku Tengah	X2	O4
		SHS 39 Salahutu	X2	

(Modified from Supratman et al., 2021)

Research Samples

The population of this research was all the students of Class X Senior High Schools (SHS) in Central Maluku, Maluku Province, Indonesia. Two schools were randomly selected using random sampling technique. The selected schools were SHS 3 Maluku Tengah and SHS 39 Salahutu. Each of these schools only had two classes. Therefore, the two classes were used as the experimental class (X1) and the control class (X2). Each class consisted of 24 students. Thus the total students of all classes were 96 students.

Instrument

The instruments used in this research were an essay test and digital literacy observation sheet. The essay test instrument consists of questions of application level, analysis, synthesis, and evaluation (Table 2). The essay test was given before and after the learning process to measure the students' cognitive learning results and creative thinking skills in learning the concepts of ecosystem. In addition, the digital literacy observation sheet was given during the learning process. The digital literacy observation sheet consisted of several indicators, namely analyzing information, synthesizing information, comparing information from various learning sources, presenting information, evaluating information, evaluating learning sources, using information ethically (Launuru et al., 2021). Moreover, before the essay test was used, the validity and the reliability of the test were initially analyzed using SPSS 18.0 (Table 3).

Table 2
Specification of the instrument for the essay test

Aspects Taught	Application (40%)	Analysis (20%)	Synthesis (20%)	Evaluation (20%)	Total (100%)
Ecosystem components (50%)	4	1			5
Interactions in food chains and webs (20%)			2		2
Biogeochemical cycle (30%)		1		2	3
Total (100%)	4	2	2	2	10

Table 3
The results of the validity and reliability of the essay test

Item number	r_{XY}	Significance Value	Interpretation	Cronbach's Alpha Value	Significance Value	Interpretation
1	0.387	p>0.05	Valid	0.659	p>0.05	Reliable
2	0.570					
3	0.106					
4	0.517					
5	0.742					
6	0.944					
7	0.615					
8	0.079					
9	0.887					
10	0.609					

Procedure

The learning procedures were carried out based on the predetermined plan, namely a pretest was administered to the experimental class and the control class in the both schools, the learning activities based on the steps of the learning models, and the posttest was administered in the experimental class and the control class. The steps of the learning models are presented in Table 4 and Table 5.

Table 4

The Stages of the STEAM integrated with PjBL learning model

STEAM Aspects	PjBL stages	Integration
Science (Concepts of Science) **Technology** (Digital Technology) **Engineering** (Planning, designing, Implementing) **Art** (neatness, appropriateness, and esthetics) **Mathematics** (the study about calculation, measurement, numbers, and etc,.)	Planning Creating Presenting	1. Teachers empower the students to design the concepts of science related to ecosystem to find a contextual problem. 2. Teachers empower the students to search information through internet using laptops, smartphones, or computers. 3. Students and teachers design the project plan collaboratively. 4. Students carry out the project (measuring the area of ecosystems, calculating the individual density of ecosystems, calculating evaporation rate, photosynthesis rate, measuring oxygen levels) according to the plans that have been made. 5. Students make products that contain aesthetic value. 6. The students present the results of the projects and products in groups before the class.

(Rumahlatu & Sangur, 2019)

Table 5

The Stages of STEAM integrated with PBL learning model

STEAM Aspects	PBL Stages	Integration
Science (Concepts of Science) **Technology** (Digital technology) **Engineering** (Planning, designing, implementing) **Art** (neatness, appropriateness, and esthetics) **Mathematics** (the study about calculation, measurement, numbers, and etc,.)	1. Orientation of the students to the problems 2. Organizing the students to learn 3. Guiding the students to do individual investigation and group investigation 4. Problem solving and providing solutions Report Presentation	1. Teachers empower the students to find scientific problems. 2. Teachers organize the students to analyze scientific problems using their prior knowledge. 3. Teachers empower the students to use technology (smartphones, laptop, etc) to access information. 4. Students do problem solving activities using experiment student worksheets. 5. The students do the exercises in the student worksheet related to measurement and calculation, and then the teachers empower the students to answer the exercises in the student worksheets by considering the values of esthetic. 6. The students present the results of their work in the form of projects, which will then be observed and assessed. A reflection is then done on the learning activities and the project results.

(Simone, 2014)

Data Analysis Techniques

The research data were analyzed using inferential statistics (ANCOVA and ANOVA). The Ancova test was used to know the effect of STEAM integrated with PjBL and PBL learning models on students' cognitive learning results and creative thinking. Moreover, the Anova test was used to know the effect of the integration of STEAM with PjBL and PBL learning models on the students' digital literacy. Before the inferential analyses were performed, the research data were initially tested for the homogeneity and the normality of the data. The homogeneity test used Levene test, while the normality test used the Kolmogorov-Smirnov test (Table 6). These data analysis techniques were performed with the assistance of Excel application and SPSS for Windows 18.0 version.

Table 6.
The results of the homogeneity and normality data analyses

Variables	Levene Value	Sig.	Description	Kolmogorov value	Sig.	Description
Cognitive learning results	1.364	.140	Homogenous	.126	.053	Normal
Creative thinking	.812	.370	Homogenous	.109	.200	Normal
Digital literacy	1.911	.170	Homogenous	.124	.064	Normal

RESULTS AND DISCUSSION

The effect of the integration of STEAM with PjBL and PBL learning models on students' cognitive learning results

The results of Ancova analysis showed that learning models had an effect on students' cognitive learning results with p<sig.0.05 (Table 7). This shows that the implementation of STEAM integrated with PjBL and PBL had an effect on students' cognitive learning results in learning about the concepts of ecosystem. Furthermore, to know which integration of learning models had more significant effects on the students' cognitive learning results, the post hoc LSD test was performed (Table 8). The results of the post hoc LSD test (Table 8) show different notations. The different notations indicate that the integration of STEAM with PjBL learning model had more significant effect towards the cognitive learning results of class X students of SMA 3 Maluku Tengah and SMA Negeri 39 Salahutu senior high schools in learning the concepts of ecosystem than the integration of STEAM with PBL model.

Table 7
The results of ANCOVA analysis on the effect of learning models on students' cognitive learning results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	1464.358[a]	2	732.179	14.363	.000
Intercept	159101.979	1	159101.979	3121.015	.000
Pre_test	96.071	1	96.071	1.885	.173
Learning_model	1372.567	1	1372.567	26.925	.000
Error	4740.920	93	50.978		
Total	685782.183	96			
Corrected total	6205.278	95			

Table 8
Results of LSD test

Learning models	Average	Notation
STEAM integrated with PjBL model	87.9117	a
STEAM integrated with PBL model	80.3610	b

The results of the ANCOVA analysis show that the Integration of STEAM with PjBL and PBL learning models had a significant effect on students' cognitive learning results (Table 7). This is because the learning stages that had been designed for learning were in accordance with the integration of STEAM with PjBL and PBL learning models. The first stage of the two learning models integrated with STEAM was introducing the students with problems which were related to scientific concepts, namely ecosystem. However, there was a significant difference between the two integrated learning models. In the STEAM-PjBL learning model, the students did the problems through projects, while the students in the STEAM-PBL model did the problems by initially identifying the problems. According the Naji et al. (2020), project-based learning emphasizes on contextual project-based tasks, analyzing problems, giving solutions through the use of technology. The next stage was using technology, namely smartphones, to search information online to solve the problems that had previously been formulated. After that, in the STEAM-PjBL learning class the next stage was that the students carried out projects, while the students in

the STEAM-PBL answered the Experiment student worksheet. Brundiers and Wiek (2013) explained that the difference between PjBL and PBL learning models laid on the categories of the main activity and the principal organization. The main activity in the PjBL was that the students produced products and did projects, while the main activity in the PBL was on investigating problems and focusing on learning tutorial. In addition, the final results of the STEAM-PjBL learning model were that the students presented their product in the form of artificial ecosystem completed with individual density, hydrologic cycle replica, and carbon, nitrogen which occurred in the ecosystem, and food chain or food web. While the final results of the learning activities in the STEAM-PBL learning model was that the students reported the results of the group discussion related to the experiment student worksheet.

The difference in the learning activities and the learning processes between the two learning models integrated with STEAM could have an effect on the students' cognitive learning results. The results indicated that the average scores of the students' cognitive learning results in the STEAM-PjBL class were higher than those of the students in the STEAM-PBL class. This could be explained that the students in the STEAM-PjBL class constructed their understanding about the concepts of ecosystem through searching information, direct measurement, and constructing a scientific product. The students in the STEAM-PBL class were also trained to identify scientific problems, searching information using technology, measuring and calculating in experiments related to the concepts of ecosystem, having discussion and making conclusions through student worksheet. However, this condition provided the students with different ways in understanding the concepts of ecosystem and applying the concepts in the final test. Therefore, the average scores of the final test of the students in SHS 3 Maluku Tengah and SHS 39 Salahutu taught using different learning models were also different. The students' learning experience and concepts were developed based on the product that the students produced during the project-based learning processes where the students constructively learned using research-based learning approach towards an issue or problem (Grant, 2002). Similar research results were reported by Simbolon and Koeswanti (2020) that the PJBL learning model was better in empowering the students' learning results than the PBL learning model was. Moreover, Mills and Treagust (2003) emphasized the difference between PjBL and PBL learning models on the aspect of the learning period. In the PjBL learning model, the project to be carried out could be complex or simple depending on the particular learning period. While in the PBL learning model, the students identified problems through problem solving activities and there was not any predetermined learning period.

The effect of the integration of STEAM with PjBL and PBL learning models on students' creative thinking skills

The results of ANCOVA analysis showed that learning models had an effect on students' creative thinking skills with p<sig.0.05 (Table 9). This shows that the implementation of STEAM integrated with PjBL and PBL had an effect on students' creative thinking skills in learning about the concepts of ecosystem. Furthermore, to know which integration of learning models had more significant effects on the students' creative thinking skills, the post hoc LSD test was performed (Table 10). The results of the post hoc LSD test (Table 10) show different notations. The different notations indicate that the integration of STEAM with PjBL learning model had more significant effect towards the creative thinking skills of class X students of SHS 3 Maluku Tengah and SHS 39 Salahutu in learning the concepts of ecosystem than the integration of STEAM with PBL model did.

Table 9
The effect of learning models on students' creative thinking skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	670.071[a]	2	335.035	7.009	.001
Intercept	61526.034	1	61526.034	1287.050	.000
Creative_pre	210.696	1	210.696	4.407	.038
Learning_models	557.062	1	557.062	11.653	.001
Error	4445.763	93	47.804		
Total	646036.000	96			
Corrected total	5115.833	95			

Table 10
The results of LSD test

Learning models	Average	Notation
STEAM integrated with PjBL model	83.8958	a
STEAM integrated with PBL model	79.5208	b

The results of the ANCOVA analysis show that the integration of STEAM with PjBL and PBL learning models had an effect on students' creative thinking skills (Table 9). Meanwhile, the average value of the integration of

STEAM with PjBL is higher than the integration of STEAM with PBL (Table 10). This shows that the integration of STEAM with PjBL is better able to accommodate the creative thinking skills of SHS 3 Maluku Tengah and SHS 39 Salahutu. Moreover, similar research results were reported by Anazifa and Djukri (2017) that there was a difference in the average scores of the creative thinking skills between the students in the PjBL and PBL learning models, which were 70.38 and 59.77 respectively. Ridlo et al. (2020) explained that Project learning integrated with STEAM had an effect on students' creative thinking skills in learning the concepts of water purification. Thus, it can be explained that the integration of STEAM with PjBL learning model was more effective in empowering the creative thinking skills of the students of Class X in SHS 3 Maluku Tengah and SHS 39 Salahutu in learning the concepts of ecosystem than the integration of STEAM with PBL learning model. This was influenced with many factors, one of which was the learning stages of the two learning models. According to Awang (2007), the project-based learning empowers the students to obtain knowledge and trains their creativity in learning as well as doing interpretation. Meanwhile, at the implementation of PBL learning model, the students' performance is assessed through problem solving, and the learning results are obtained from writing learning reports. Rahmawati et al. (2019) also reported that STEAM approach integrated with PjBL could empower students' creative thinking, analyzing skill, and interpretation skill. When the students are planning the steps to carry out a project, the students are trained to empower their creative thinking skills, namely creative in searching digital information, organizing the stages of the projects, and making products. Sheu and Chen (2014) explain that creative thinking is the ability to find ideas and solutions to problems. Moreover, Supratman et al. (2021) explain that the problem-solving activity that the students do during the learning process can improve their creative thinking skills.

The effect of the integration of STEAM with PjBL and PBL learning models on students' digital literacy

The results of ANOVA analysis show that the learning models do not have a significant effect on students' digital literacy with p>sig.0.05 (Table 11). This shows that the implementation of STEAM integrated with PjBL and PBL did not have a significant effect on the students' digital literacy in learning the concepts of ecosystem.

Table 11
The effect of learning models on students' digital literacy

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	18.375	1	18.375	1.615	.207
Within groups	1069.583	94	11.379		
Total	1087.958	95			

During the research process, the students followed the learning stages of the STEAM-PjBL learning model or the STEAM-PBL learning model. During the learning process in both learning models, the students actively used their smartphones to access the internet through Scholar, Google, or Mozilla search. Nelson et al. (2011) explained that accessing information using internet or digital device can be easily understood by the students, and it can improve the learning. As a result, the process of the information search by the students can be easier and faster. Thus, it helps improve the students' digital literacy in the future. Based on the learning stages of the two learning models which used smartphones to access the internet for search, finding, and using information, the results of the Anova analysis on the integration between STEAM with PjBL and PBL learning models did not have an effect on the digital literacy of the students of SHS 3 Maluku Tengah and SHS 9 Salahutu with p>sig.0.05 (Table 11).

The results of Ambarwati et al. (2019) explains that all learning Systematics of Animal Biology can improve students' digital literacy through searching for information from websites, so that students can produce scientific papers well. Moreover, Setiawan et al. (2021) also explained that the students' digital literacy in learning the concepts of Protista improved through analyzing and using information activities. In addition, Utama et al. (2019) argued that using technology in learning not only improves students' digital literacy but also improves students' concept gaining. Furthermore, Saxena et al. (2018) stated that the use of smartphones for searching information could revolutionize the students' learning activities. In learning biology, this ecosystem concept can also empower digital literacy using the integration of STEAM with PjBL and the integration of STEAM with PBL. Thus, the results of this research have showed that in this 4.0 era, the implementation of various models which empower the students' ability at searching information using digital device can improve the students' digital literacy.

CONCLUSION

The results of this research show that the integration of STEAM with PjBL and PBL learning models had an effect on students' cognitive learning results and creative thinking skills. This means that the integration of STEAM with PjBL and PBL learning models is effective in empowering students' cognitive learning results and creative thinking skills. However, the integration of STEAM with PjBL and PBL learning models did not an effect on students' digital literacy. This is related to the students' poor ability in using digital technology to search information about the concepts of ecosystem. In addition, the results of this research can be the basis for

integrating STEAM with other learning models to improve students' higher order thinking skills and literacy in this digital era.

ACKNOWLEDGMENT

The authors would like to thank the SHS 3 Central Maluku and SHS 39 Salahutu, Indonesia for providing facilities during the research.

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