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Integrated project-based e-learning with science, technology, engineering, arts, and mathematics (PjBeL-STEAM): its effect on science process skills

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ABSTRACT

This research aims to analyze the effect of the project-based e-learning with science, technology, engineering, arts, and mathematics (PjBeL-STEAM) learning model on students' science process skills. The PjBeL-STEAM learning model emphasizes on project activities with interdisciplinary through online learning. The research employs a quasi-experimental method with a pretest-posttest control group design. The research population includes students of grade X in ecosystem learning at one of public senior high schools in Jakarta Timur, Indonesia. The research sample consists of 72 students taken using purposive sampling. The main projects in PjBeL-STEAM learning include creating an animation of biogeochemical cycles and independent experiments. The research data on science process skills are collected using pretest and posttest questions. Students' response to learning uses Likert scale instruments. The data analysis technique employs an Independent sample t-test. The research results indicate that the PjBeL-STEAM learning model provides better effects on science process skills than in control class. It is necessary to implement the PjBeL-STEAM learning model in online Biology learning to improve science process skills in better ecosystem learning.

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INTRODUCTION

The success of students' science learning affects by numerous factors. One of them is science process skills to learn scientific objects. The science process skills are a combination of critical thinking and inquiry in scientific field that requires cognitive and psychomotor skills to find theories, concepts, and facts (Rustaman, 2003; Nworgu & Otum, 2013; Tsaniyyah, Marianti, & Isnaen, 2019). Literally, science learning relies on scientific process that requires science process skills (Bahtiar & Dukomalamo, 2019; Handayanto & Dasna, 2018).

It is crucial to train the science process skills to students in learning as it is capable of directing to mental, physical, and social development (Juhji & Nuangchalerm, 2020; Gürses, Çetinkaya, & Elif, 2015). Developing science process skills could facilitate biology learning that allows students to learn actively, possess a sense of responsibility, and enhance skills with scientific methods (Ongowo & Indoshi, 2013). The science process skills could be developed with activities that involve formulating hypotheses, predicting, planning, experiment, interpreting, and communicating (Indriani & Mercuriani, 2019; Blohm et al., 2014). Implementing the skills in learning provides an opportunity for students to directly locate what they learn and develop content understanding and in turn, more interesting and fun learning (Rahayu & Anggraeni, 2017; Handayanto & Dasna, 2018).

Biology is one of subjects in science, especially in secondary school level (Ristanto et al., 2018; Harahap et al., 2020). Biology learning studies various phenomena as well as organism and its environment. Many people currently still consider biology as a difficult and unexciting subject to learn (Kristiani, Lisanti, & Ristanto, 2020; Gustiantini, Aeni, & Jayadinata, 2017). Biology also deems a less desirable subject as it only discusses about theories, laws, and concepts of a content (Sujana, 2014). Moreover, biology learning at schools mostly utilizes a conventional learning model with memorizing system and lack of thinking skill development (Ristanto et al., 2018; Farida, Hadiansah, Mahmud, & Munandar, 2017).

In biology learning, students are supposed to gain skills to find facts or develop principles of biology through observation of problems relevant to everyday life environment (Chatib, 2017; Lidi & Daud, 2019; Torkar, 2019). Ecology as a branch of biology science deals with the relations of organisms and their environment (Aprilia & Suryadarma, 2020; Arnott, Palaiologou, & Gray, 2019). A discourse of numerous and broad biology study involves a high analysis and it won't be sufficient through merely memorizing theories in its learning (Yorek, Ugulu, Sahin & Dogan, 2010).

The fact is that the ecology content learning process by teachers at school has involved a discussion; however, it is not maximal (Aprilia & Suryadarma, 2020; Harahap et al., 2020). It is due to assessment of the learning process that is limited to exercises (Zeidan & Jayosi, 2015; Zeitoun & Hajo, 2015). Topics of ecology demands direct observation and experiments that involve students (Nurhayati, Panjaitan, & Djuanda, 2016; Hartini & Qohar, 2018).

A learning design applied must change. Several learning models could assist to activate students in establishing students' independent attitude. The project based learning (PjBL) is a learning design that could empower cognitive, affective, and psychomotor aspects so that it could improve student skills (Treacy et al., 2011; Morgan & Slough, 2013). The PjBL is a learning model that encourages students to be active, capable of implementing their knowledge, and develop various thinking skills and concrete skills (Özer & Özkan, 2012; Condliffe, Quint, Visher, & Bangser, 2017). Previous study by Siwa (2013) and Maghfiroh, Susilo, & Gofur (2016) suggests that the PjBL learning could improve students' science process skills.

In addition to the PjBL learning implementation, an appropriate learning approach is necessary to bridge a gap between academic knowledge and concrete application. The approach, in this regards, is STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning implementation (Quigley, Herro, & Jamil, 2014; You, 2017). STEAM leads students to develop critical thinking skills, problem solving skills, and collaborating skills (Buonincontro, 2018; Dejarnette, 2018). The STEAM learning for students is not merely theoretical but also includes a practice in the form of a project; thus, students attain direct learning and it is in accordance with the essence of science (Rustaman, 2003).

An alternative to maximize learning outcome is by integrating the PjBL and STEAM. The integration is expected to be able to complement and support each other and optimize students' science process skills. The integration of STEAM and the PjBL model is capable of producing a meaningful learning, enhancing interest to learn, and solving problem as well as supporting career (Tseng, Chang, Lou, & Chen, 2013).

The learning media utilization in learning process could optimize content delivery to students (Bell, 2010). In the even semester of 2020, education process in Indonesia is conducted online due to the Covid-19 pandemic. The effectiveness of the STEAM has been proven in learning quality improvement (Utomo et al., 2020; Acan & Acan, 2019). In addition, various studies on the e-Learning-based PjBL learning model indicates an improvement in students' concept mastery, learning motivation, and learning outcome (Na'imah, Wardani, & Supartono, 2015; Made, Suranti, & Sahidu, 2016). Therefore, it is necessary to modify the PjBL model with the e-learning-based STEAM (PjBeL-STEAM) to examine learning outcome achievement in the context of science process skills in ecology topic. This research aims to analyze the effect of modification of a PjBeL-STEAM design on students' science process skills in ecology content among senior high school students.

METHODS

Research Design

The research type is a quantitative research that was designed using a quasi-experimental method (Sugiono, 2012). The research learning design is illustrated in Table 1. The research design used was pretest and posttest control group design. The research independent variable was PjBeL-STEAM learning model, whereas the dependent variable was science process skills.

Table 1
Constellation of Pretest-Posttest Control Group Design.

Class	Pretest	Treatment	Posttest
E	O_1	X	O_2
K	O_1	O	O_2

Note: E=Experimental class (PjBeL-STEAM); K= Control class (*e-Learning*); O_1= Pretest of science process skills; O_2= Posttest of science process skills; X= Treatment, O= Control.

Population and Samples

The research was conducted at one of public senior high schools in East Jakarta in grade X of MIPA of academic year of 2019/2020 with population of 144 students. Samples were selected using purposive sampling. The sampling carried out using an equivalence test in four classes of Grade X of MIPA using average Biology score obtained in previous subject. The equivalence test results indicated that the X MIPA D class and X MIPA A class were equal. Next, determination of experimental class and control class carried out by involving biology teacher. The number of sample consisted of 36 students of X MIPA D class as an experimental class and 36 student of X MIPA A class.

Instrument

The research instruments consisted of test and non-test instruments (questionnaire and observation sheets). The test instrument was employed to measure the science process skills, whereas the non-test instrument was utilized to measure the learning process implementation and students' response to the learning. The science process skills instrument was in the form of essay questions by referring to Maradona (2013). The grid of the science process skills instrument is presented in Table 2. Construct and content validity test by expert was conducted prior to the use of the instrument in the research. The validity test obtained an average value of 79.18, which is within a valid criterion. An empirical validity test of the instrument items carried out using the Pearson Product Moment formula resulted $r > r_{table}$ with minimum range of 0.224. It indicated that 15 questions tested were all valid. Further, a reliability test conducted using Cronbach's Alpha formula that generated a value of $0.949 > 0.6$ means that the instruments were reliable.

Table 2
Indicators of Science Process Skills in Ecological Education.

Indicator	Description	Total Question	Example
Formulating hypotheses	Formulating a reasonable hypothesis in accordance with testable theories of how or why something happened	2	 Rani wants to plant a staghorn fern in her yard. Since she has limited area, Rani takes the initiative to attach the plant to a mango tree (as in the pic). Make 2 hypotheses according to the picture!
Planning an Experiment	Students plan an experiment procedure in accordance with the experiment objectives	2	 Fani will conduct an experiment of creating an artificial water ecosystem. The observation aims to learn the effect of aquatic plants on the survival of aquatic animals. Write down a design of tools and materials along with steps to create an aquascape!
Interpreting data	Analyzing results, combining	2	

	information based on theories and results of experiment		 During a forest fires in Kalimantan in 2019 ecosystems are changing and it is categorized as a national disaster. Suggest 2 ideas or activities that could be done as an effort to prevent forest fires
Predicting	Connecting data of experiment results to theories	3	 The municipal government of Gresik along with PT Matahari Sakti and Lions Club Surabaya carry out an activity of planting 10 thousand mangroves at Cape of Widoro Mengare as one of natural preservation efforts. The mangrove trees function to prevent abrasion and play an important role for the life sustainability of marine biota. Write 2 possibilities if the number of *Episesarma versicolor* (violet vinegar crab) population increases in a mangrove ecosystem!
Applying concept	Indicating a reciprocal relationship of suitability between experiment and conclusions drawn	2	 Human activities often influence the environmental condition, such as siltation of a river, residential area along the riverbank, and garbage that accumulates in sluice and blocks water flow; thus, floods haunt residential areas in rainy season. According to your analysis what activities that have a potential to cause floods, explain!

Communicating	Reporting the experiment results in the form of a structured report	2	Following is the results of observation in three different locations to compare surface temperature in three conditions: under a tree, a grass field, and asphalt: a. Surface temperature of a grass field measured at 9.00 AM is 26^{0} C, at 9.20 AM is 28^{0}C, at 9.40 AM is 29.3^{0}C, and at 10.00 AM is 31.6^{0} C. b. Surface temperature under a tree measured at 9.00 AM is $25,8^{0}$C, at 9.20 AM is $27,1^{0}$C, at 9.40 AM is 28^{0} C, and at 10.00 AM is 29^{0} C. c. Asphalt surface temperature measured at 9.00 AM is 27^{0} C, at 9.20 AM is 30^{0} C, at 9.40 AM is $33,7^{0}$C, and at 10.00 AM is 34^{0}C. Create an observation result table based on the generated data!

Procedure

The research carried out in long distance learning using an application with internet network. It utilized WhatsApp and Google Meet applications as a communication medium and Google Classroom as a medium to upload content. Students in the experimental class and control class were given a pretest prior to ecology learning. The pretest aims to measure students' initial ability of science process skills. The experimental class was taught using PjBeL-STEAM learning model, whereas the control class was taught using e-Learning model. The research conducted in four meetings from March to April 2020. In the last meeting, students in both classes were given a posttest to identify their science process skills after treatment.

The PjBeL-STEAM learning implementation referred to Laboy & Rush's (2010) syntax. The PjBeL-STEAM learning process by teachers and students (as illustrated in Figure 1) included: (1) Reflection: teachers provide stimulus related to problem context to motivate students to start an investigation and connect what they know and what they learn, (2) Research: students are given an opportunity to collect relevant information and teacher will guide them to make their concept understanding of the project concrete, (3) Discovery, which is the development of student ability in establishing habit of mind from designing a process and designing a project, (4) Application, which is testing the product created and improving the product if errors occur as well as discussion to look for solution in project-related problem solving, and (5) Communication: students present their product and teacher assess the product's end result.

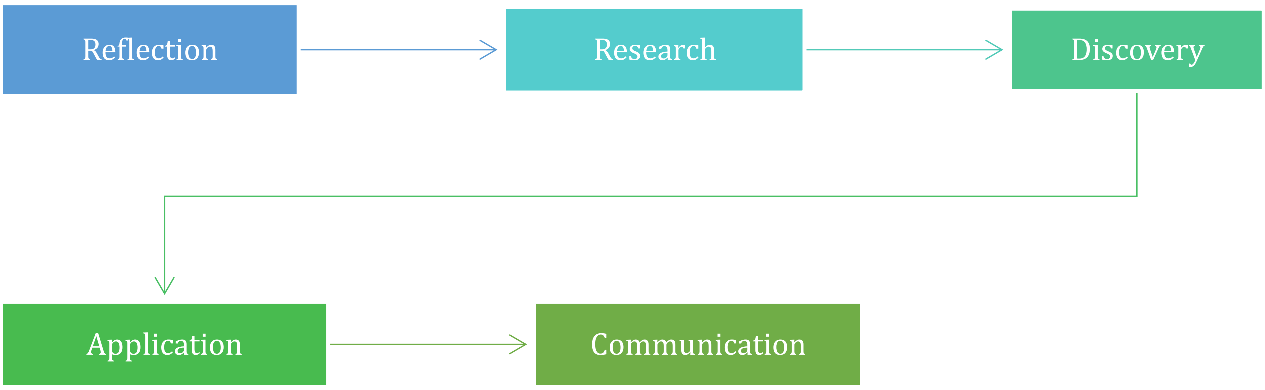

Figure 1. PjBeL-STEAM Syntax.

Data Analysis Techniques

Data analysis employed in the research was descriptive test in the form of average score of pretest and posttest and standard deviation. Data analysis included prerequisite tests and hypothesis testing. The prerequisite tests used normality test with Kolmogorov-Smirnov and homogeneity test with Levine Test. The normality test result suggested that the data were normally distributed in the experimental and control class (Table 3). The homogeneity test indicated that the data were homogeneous in both classes (Table 4). The hypothesis testing used independent sample t-test. The results of learning implementation analysis and students' response to the PjBeL-STEAM learning were analyzed in percentage.

Table 3

Normality of Science Process Skills Pretest and Posttest.

No	Class	Sample	Science Process Skills		Sig. α	Description
			Pretest	Posttest		
1	Experiment	36	0.200	0.200	0.05	Normal
2	Control	36	0.200	0.200	0.05	Normal

The normality calculation result as presented in Table 3 suggested that the significance of pretest and posttest for experimental and control class was greater than α = 0.05. It meant that the data of science process skills were normally distributed.

Table 4

Homogeneity of Science Process Skills.

Levene Statistic	df1	df2	Sig.	Sig. α Value	Description
0.596	1	70	.443	0.05	Homogeneous

The results of homogeneity calculation as displayed in Table 4 resulted a significance that was greater than α = 0.05. It indicated that the average score of pretest and posttest in both classes was homogeneous.

RESULTS AND DISCUSSION

The research data were taken from experimental class and control class. The results of science process skills analysis comprised pretest and posttest. The science process skills test carried out on 72 students. Description of the skills data is presented in Table 5.

Table 5

Descriptive Statistics of Science Process Skills.

Indicator	Average			
	Experimental Class		Control Class	
	Pretest	Posttest	Pretest	Posttest
Total Score	1446.67	22900.00	1340.00	2209.00
Mean	39.19	63.61	38.22	61.39
Min	10.00	40.00	23.33	48.33
Max	70.00	85.00	60.00	78.33
Standard Deviation	18.51	9.34	9.58	6.94
Variance	342.68	87.23	91.61	48.18

The data analysis results before the implementation of PjBeL-STEAM learning model in ecology learning indicated that the achievement of students' average score was 39.19. There was an increase in the results of average pretest and posttest with students who were taught with PjBeL-STEAM learning had higher score than those students who were taught using e-Learning, which was 63.61.

Table 6
Average Science Process Skills per Indicator with the PjBeL-STEAM Learning Model.

No	Indicator	Average					
		Experiment		Increase (%)	Control		Increase (%)
		Pretest	Posttest		Pretest	Posttest	
1	Formulating hypotheses	51.50	87.50	70.00	49.50	81.50	65.00
2	Predicting	52.67	79.00	52.00	49.67	75.33	50.00
3	Planning an experiment	43.50	90.50	108.04	42.50	85.00	100.00
4	Communicating	55.50	86.67	56.16	50.00	83.00	66.00
5	Interpreting	58.00	87.00	50.00	52.50	83.50	59.40
6	Asking Questions	65.33	88.67	35.72	63.33	89.33	41.05
7	Applying Concept	43.00	85.50	99.00	41.50	82.50	98.49

Referring to data in Table 6, the average pretest and posttest based on indicators of science process skills, in overall, experienced an increase in both experimental and control class. There were four indicators of science process skills in the experimental class that had higher increase compared to the control class. These indicators included planning an experiment (108.04%), applying concept (99%), formulating hypotheses (70%), and predicting (52%).

The enhancement in the science process skills in the experimental class was due to the students who were trained using PjBeL-STEAM learning model by constructing knowledge independently through learning process-related scientific activities. It is in line with research results of Henriksen (2014); Smith, Swaminathan, & Schellenberg (2015); Afriana, Permanasari, & Fitriani (2016); Zubaidah (2019) indicated that a project-based learning that is integrated with STEAM teaches students to innovate and be creative in sharpening skills to create a project and improve students' performance during the learning.

The PjBeL-STEAM model learning implementation referred to Laboy & Rush's (2010) syntax. The achievement of syntax implementation percentage experienced an increase as a whole (Figure 2). The implementation of the PjBeL-STEAM learning syntax increased in learning of ecosystem component chapter (meeting 1) of 74.01%, interaction in an ecosystem chapter (meeting 2) of 84.52%, energy flow chapter (meeting 3) of 90.22%, and biogeochemical cycles chapter (meeting 4) of 96.50%.

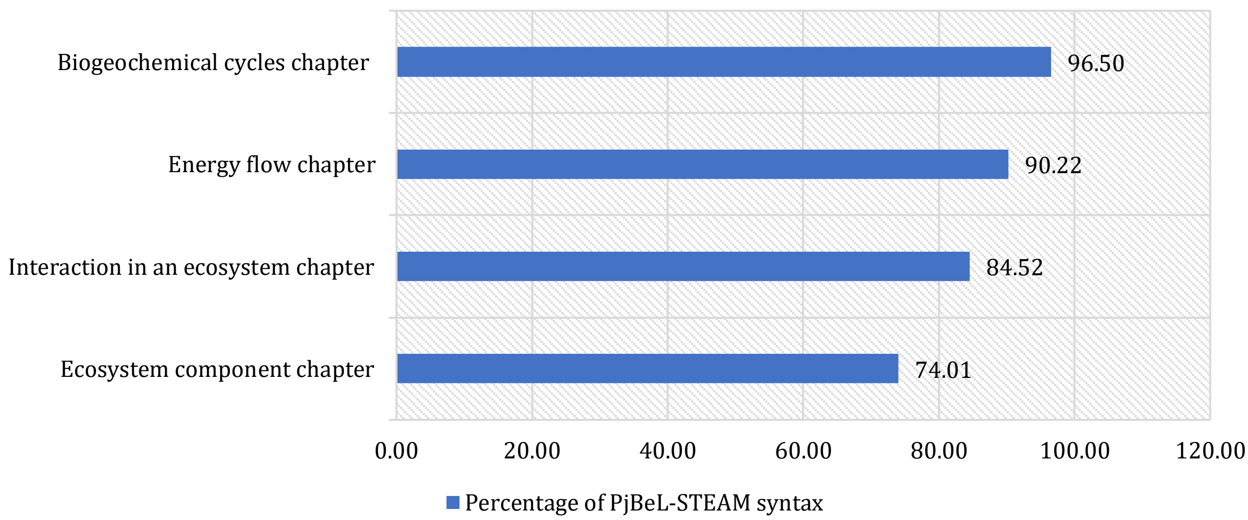

Figure 2. Implementation of PjBeL-STEAM Syntax

Figure 3 illustrates examples of the results of biogeochemical cycle animated product made by the students. Figure 4 shows students present their experiment result on interaction of abiotic and biotic components in an ecosystem. Each student was asked to integrate science, technology, engineering, art, and mathematics aspects in working on the animation project and independent practice. The benefit of the STEAM approach is to make students independent, become innovators, to think logically and possess good technology literacy (Acan & Acan, 2019; Stohlmam, 2012).

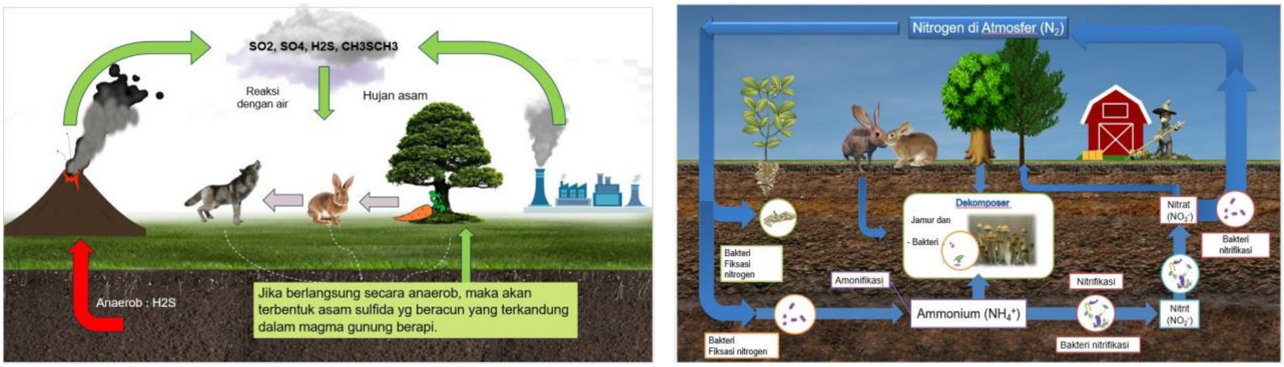

Figure 3. Examples of students' biogeochemistry animation results: sulfur cycle (left) and nitrogen cycle (right).

Figure 4. Examples of presentation of independent experiment results on interaction of abiotic components (solution used to water the plants) and abiotic components (sprouts) on plant growth rate.

Table 7
Students' Response to Learning.
Note: SA (strongly agree), A (agree), U (uncertain), DS (disagree), and SD (strongly disagree)

No	Response	Percentage (%)				
		SA	A	U	DS	SD
1	Develop science skills	88.80	66.70	38.90	5.60	0
2	Learning leads to a student-centered style	80.50	69.50	33.30	16.70	0
3	Guidance by teacher	44.40	33.30	22.20	0	0
4	Environmentally awareness attitude	44.40	36.10	11.10	8.30	0
5	Meaningful learning	86.10	75.00	27.80	11.10	0
6	STEAM implementation	94.30	83.40	63.80	36.20	0
7	Facilitate ecology concept mastery	88.40	55.60	41.60	13.90	0
8	The use of internet technology simplify the learning process	83.30	77.70	16.70	11.10	0
	Total	610.2	497.3	255.4	102.9	0
	Mean	76.28	62.16	31.93	12.86	0

Students' response to the PjBeL-STEAM learning that had eight indicators generated an average percentage of 76.28% with strongly agree category. It indicates students' positive response to the PjBeL-STEAM learning. The overall explanation of students' response is elaborated in Table 7. The data analysis of the hypothesis testing was conducted using independent sample t-test of the science process skill with α = 0.05. The summary of the test result is indicated in Table 8.

Table 8
Independent sample t-test of Pretest-Posttest of Science Process Skills Indicators in Experimental and Control Class.

No	Indicator	Pretest		Posttest	
		Sig	Conclusion	Sig	Conclusion
1	Formulating hypotheses	0.090	No differences	0.006	There are differences
2	Predicting	0.482	No differences	0.028	There are differences
3	Planning an experiment	0.091	No differences	0.000	There are differences
4	Communicating	0.253	No differences	0.044	There are differences
5	Interpreting	0.089	No differences	0.021	There are differences
6	Asking questions	0.212	No differences	0.000	There are differences
7	Applying concept	0.283	No differences	0.024	There are differences

The hypothesis testing used independent sample t-test of pretest and posttest data to find out the PjBeL-STEAM model effect on science process skills. The data were analyzed using SPSS version 23. Table 7 indicates significance values that are greater than α = 0.05 meaning that there were no differences in the experimental class and control class. It can be concluded that the science process skills in both classes was equal before treatment applied.

The results of independent sample t-test of posttest data in the experimental class and control class indicated significance values that were smaller than α = 0.05. It meant that there were differences in the science process skills after the students learned using the PjBeL-STEAM model in the experimental class and e-Learning in the control class. The research is relevant to research results of; Maghfiroh et al., (2016); and Wijanarko, Supardi, & Marwoto (2017) concluded that there were differences in science process skills using the PjBeL-STEAM learning model.

The current research results generally indicated an effect of the PjBeL-STEAM learning model on the science process skills. Improvement in the science process skills in the experimental class that used the PjBeL-STEAM learning model was generally outperformed the control class (Table 5). The PjBeL-STEAM learning is suitable to be applied in learning as it could encourage students to learn about ecology through exploration, inquiry, and problem solving (Asghar, 2012; Afriana, 2016).

The research finding in Table 6 indicates the achievement of the science process skills indicators. There were four indicators in the pretest and posttest results with PjBeL-STEAM learning model that experienced higher increased compared to the control class. The four indicators included planning an experiment, applying concept, formulating hypotheses, and predicting. It is relevant to Wulandari (2016) stated that the PjBeL-STEAM learning is a learning model that involves students in learning knowledge and skills through systematic searching and investigation process.

Data of students' response to the PjBeL-STEAM learning were acquired from questionnaires given after the learning. Table 7 presents the percentage results of student response questionnaire that consisted of eight indicators. Based on the percentage, STEAM implementation indicator had the highest percentage compared to other indicators, which was 94.30%. The results indicated that implementing STEAM brought some benefits for students. Hodgin (2010) and Lou (2011) opined that STEAM approach allows students to understand integrated knowledge and increase student interest to science and technology; thus, it strengthens students to cope with life problems.

The data result of the science process skills achievement as indicated in Table 8 suggested that there were differences in the science process skills result before and after the treatment using PjBeL-STEAM learning model. It implied that the PjBeL-STEAM learning model is appropriate for learning. It is in line with research results of Siwa, Muderawan, & Tika (2013) and Maghfiroh, Susilo, & Gofur (2016) indicated that the STEAM-integrated PjBL improved students' science process skills.

Improvement in the science process skills in the experimental class was explainable as the learning process implementation had been conducted according to the PjBeL-STEAM learning syntax. The PjBeL-STEAM learning syntax stages conducted in the research comprised reflection, research, discovery, application, and communication (Laboy & Rush, 2010). In the reflection stage, teacher used WhatsApp and Google Classroom media to upload the first content as a basic knowledge that was related to problems to be identified. In this stage, students were trained to formulate hypotheses. Students were required to generate ideas on problems related to ecology provided in the video and LKPD. Next, students conveyed their solutions. According to Çakici (2013); Fajarwati, Susilo, & Indriwati (2017), students need to conduct several things; for example, accepting challenges to solve problems related to the surrounding environment; thus, it will foster a sense of being challenged and desire to solve.

The research stage was conducted by involving students in the inquiry learning process. In this stage, several examples of problems to be investigated by students were presented that related to ecosystem components and energy flow. During the stage, students would ask questions actively, develop hypotheses, and look for references in printed as well as electronic media. The investigation activity shapes students to find new and never-been-thought ideas. Gürses, Çetinkaya, Do, & Elif (2015) expressed that the research stage allows students to acquire learning experience independently; therefore, this leads to new ideas related to their prior learning experience and provides positive influence in the form of ability to observe, measure, and process data.

In the discovery stage students found information related to the project. Students were also trained to interpret the information that will be validated by applying concept in the project. They would begin to compile animation project of biogeochemistry and independent experiment to be conducted. Moreover, students determined sources of reference. This will foster students' critical thinking skills, analysis, and creative and improve students' high-order skills (Carpraro et al., 2015).

On another occasion, the discovery stage is also employed for collaborating and exchanging information. Teachers carried out an initial assessment in online learning, communication of monitoring, and consultation using WhatsApp and Google Meet. Hafid, Hayami, Fatma, & Wenando (2018) and Rifa'i (2012) stated that collaboration and discussion activities during learning process are effective in constructing knowledge since students state their ideas, ask questions, give feedbacks, and evaluate. It is supported by research results of Sabara (2016); Tsaoys, (2017); Hafid, Hayami, Fatma, & Wenando (2018) indicated that the utilization of special applications as learning media brings more effective learning process and learning activity via online class.

Improvement in the applying concept indicator was due to the students in the application stage carried out a product trial. The trial will indicate whether the product is suitable to the agreed terms. Through the activity students will learn to correct any mistakes occurred to attain maximum results. Misdar (2018) opined that students experience failures due to the lack of understanding of learning objectives and low self-control so as students are helpless in coping with learning problems. Teacher role in the application stage is to guide students by assimilating their understanding through observation results or literature study.

The last stage is communication, which is a presentation of the final result via Google Meet. Besides the presentation, teachers evaluated and reflected along with students on the learning process. Teachers could compare students' prior understanding and their new understanding that was formed after the learning. It is similar to Noviyanti (2011) and Lou, Chou, Shih & Chung (2016) stated that planned communication through discussion, presentation, and express opinion supports student understanding of a learning content.

Integrating STEAM aspects to the learning process could enhance students' learning experience by practicing activities and applying of general principles of the studied content; thus, better learning outcome (Roberts, 2012; Kennedy, 2014). The STEAM aspects implemented in the research included: (1) science aspect on understanding of ecology content; (2) technology and engineering aspect by utilizing and operating internet and Ms. Office application to complete the work of project assignment. It is in accordance with a statement from Alqahtani, Vadakalur, & Abumelha (2018) that internet network-aided applications hold various functions; (3) mathematics aspect was applied in independent experiment activity where students determine and read the measurement results; and (4) art aspect could be seen from the different students' creativity results in biogeochemical cycles animation. This is relevant to research by Swaminathan, & Schellenberg (2015) and Hakim, Sulatri, Mudrikah, & Ahmatika (2019) indicated that the STEAM learning is capable of improving student's creativity, divergent thinking, innovation, and curiosity.

Factors influencing the low science process skills in the control class included students who were not trained to solve problems and the learning applied that focused merely on outcome. As a consequence, students were not trained to construct their knowledge independently; hence, they were lack of science process skills. A learning process that leads to a teacher-centered style will inhibit the establishment of values in the learning process (Acan & Acan, 2019; Stohlmam, 2012; Chusna, 2019). It was these differences in the learning process that caused the science process skills in the experimental class were higher than in the control class. The PjBeL-STEAM model implementation in the research bears some limitations. The limitations include teachers who could not directly monitor students' project activity and restriction to perform psychomotor assessment to support assessment of the science process skills. Other factors influencing the learning process implementation includes adequate internet connection and mastery of technology or internet applications to achieve optimum learning process.

CONCLUSION

The research was limited in terms of non-test assessment aspect (observation sheets) of the science process skills. It was due to the students who could not be monitored directly by the teacher. The research offers several implications, namely: (1) the PjBeL-STEAM learning model has a potential as an alternative of learning model that could facilitate the improvement of science process skills of senior high school students and (2) the PjBeL-STEAM learning model facilitates students to think independently, to explore, create, and observe. The STEAM approach that is integrated to the PjBL is potential to provide meaningful learning and train scienctific work skills through projects that are integrated with several scientific fields that facilitates learning experiences and brings significant benefits for the student life (Becker & Park, 2011; Wilson & Hawkins, 2019). Additionally, the PjBeL-STEAM learning process requires more intensive guidance and discussion to monitor students in implementing project activity to generate maximum products.

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REFERENCES

Acan, S. C., & Acan, N. L. (2019). Music notes to amino acid sequence: A STEAM approach to study protein structure. *Biochemistry and Molecular Biology Education, 47*(6), 669-671. https://doi.org/10.1002/bmb.21299

Afriana, J., Permanasari, A., & Fitriani, A. (2016). Penerapan project-based learning terintegrasi STEM untuk meningkatkan literasi sains siswa ditinjau dari gender. *Journal Inovasi Pendidikan IPA*, *2*(2), 202–212. https://doi.org/10.21831/jipi.v2i2.8561

Alqahtani, M.S., Bhaskar. C.V., Vadakalur E.K., & Abumelha. M. (2018). WhatsApp: an online platform for university level english language education. *Arab World English Journal*, *9*(4), 108-121. https://doi.org/ 10.24093/awej

Aprilia, I., & Suryadarma, I. G. P. (2020). E-module of mangrove ecosystem (emme): development, validation and effectiveness in improving students' self-regulated. *Biosfer: Jurnal Pendidikan Biologi, 13*(1), 114-129. https://doi.org/10.21009/biosferjpb.v13n1.114-129

Arnott, L., Palaiologou, I., & Gray, C. (2019). Internet of toys across home and early childhood education: understanding the ecology of the child's social world. *Technology, Pedagogy and Education, 28*(4), 401-412. https://doi.org/10.1080/1475939X.2019.1656667

Bahtiar, B., & Dukomalamo, N. (2019). Basic science process skills of biology laboratory practice: improving through discovery learning. *Biosfer: Jurnal Pendidikan Biologi, 12*(1), 83-93. https://doi.org/10.21009/biosferjpb.v12n1.83-93

Becker, K. H., & Park, K. (2011). Effects to integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students learning: *a meta-analysis. Journal of STEM Education. 12.* Retrieved from http://www.sciepub.com/reference/73145

Bell, S. (2010). Project based learning for the 21st century: skills for thr future. *Routledge*, *83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Blohm, M., Krautter, M., Lauter, J., Huber, J., Weyrich, P., Herzog, W., & Nikendei, C. (2014). Voluntary undergraduate technical skills training course to prepare students for clerkship assignment: tutees ' and tutors ' perspectives. *BMC Medical Education*, 1–11. https://doi.org/10.1186/1472-6920-14-71

Buonincontro, J. (2018). Gathering STE(A)M : Policy, curricular, and programmatic developments in arts-based science, technology, engineering , and mathematics education introduction to the special issue of arts education. *STEAM Focus. Art Education Policy Review Journal*, *119*(2), 1–4. https://doi.org/10.1080/10632913.2017.1407979

Çakici, Y. (2013). An investigation of the effect of project-based learning approach on children's achievement and attitude in science. *The Online Journal of Science and Technology*, 3(2), 9–17. Retrieved from https://semanticscholar.org/d161/d843968b8e6339ac0406517807be3712484a.

Chatib, M. (2017). Problematika pembelajaran biologi ditinjau dari aspek kompetensi lulusan. *Prosiding Seminar Nasional Pendidikan*, *2*(1), 361–366. Retrieved from http://fkip.um-palembang.ac.id/wp-content

Chusna, N. L. (2019). Pembelajaran e-learning. *Prosiding Seminar Nasional Pendidikan KALUNI*, *2*, 113–117. Retrieved from http://www.rumahpublikasi.com/index.php/prokaluni/article/viewFile/36/20

Condliffe, B., Quint, J., Visher, M. G., & Bangser, M. R. (2017). Project based learning a literature review. *Artikel*, 1–78. Retrieved from https://eric.ed.gov/578933

Connor, A. M., Karmokar, S., & Whittington, C. (2015). From STEM to STEAM : strategies for enhancing engineering & technology education. 5(2), 37–47. Retrieved from https://online-journals.org/index.php/i-jep/article/view/4458

Dejarnette, N. K. (2018). Implementing STEAM in the early childhood classroom. *European Journal of STEM Education*, *3*(3), 1–9. https://doi.org/doi.org/10.20897/ejsteme/3878

Dilekli, Y., & Tezci, E. (2019). Thinking skills and creativity. *Journal Pre-Proof*, 100624. https://doi.org/10.1016/j.tsc.2019.100624

Fajarwati, S. K., Susilo, H., & Indriwati, S. E. (2017). Pengaruh project based learning berbantuan multimedia terhadap keterampilan memecahkan masalah dan hasil psikomotor siswa kelas XI SMA. *Jurnal Pendidikan*, 2(3), 315–321. http://dx.doi.org/10.17977/jptpp.v3i7.11291

Farida, Hadiansah, Mahmud, & Munandar. (2017). Project based learning design for internalization of environmental literacy with islamic value. *Jurnal Pendidikan IPA*, *6*(2), 277–284. https://doi.org/10.15294/jpii.v6i2.9452

Fitniani, & Nurjanah. (2019). Peranan e-learning dalam pembelajaran matematika di Sekolah menengah pertama (SMP). *Journal on Pedagogical Mathematics*, *1*(2), 102–110. Retrieved from http://journal.um-surabaya.ac.id/index.php/Pro/article/download/4338/2595

Gürses, A., Çetinkaya, S., Do, Ç., & Elif, Ş. (2015). Determination of levels of use of basic process skills of high school students. *Procedia - Social and Behavioral Science*, *191*, 644–650. https://doi.org/10.1016/j.sbspro.2015.04.243

Gustiantini, L., Aeni, A. N., & Jayadinata, A. K. (2017). Pengembangan keterampilan proses sains kelas V pada materi gaya gesek melalui pembelajaran konstektual. *Jurnal Pena Ilmiah*, *2*(1), 651–660. https://doi.org/10.17509/jpi.v2i1.10103

Hafid, A., Hayami, R., Fatma, Y., & Wenando, F. A. (2018). Optimalisasi pemanfaatan google classroom sebagai media pembelajaran di SMK negeri 1 Bangkinang. *Jurnal Pengabdian Untuk Mu Negeri*, *2*(1), 17–20. Retrieved from http://ejurnal.umri.ac.id/index.php/PengabdianUMRI/361/352

Hakim, L. L., Sulatri, Y. L., Mudrikah, A., & Ahmatika, D. (2019). STEM project-based learning models in learning mathematics to develop 21st century skills. *ITEEA Journal*, 1–5. https://doi.org/10.4108/eai.19-10-2018.2281357

Handayanto, S. K., & Dasna, I. W. (2018). Pengaruh learning cycle 5E terhadap keterampilan proses sains peserta didik kelas VIII. *Jurnal Pendidikan*, *3*(3), 286–290. http://dx.doi.org/10.17977/jptpp.v3i3.10624

Harahap, L. J., Ristanto, R. H., & Komala, R. (2020). Evoking 21st-Century Skills: Developing instrument of critical thinking skills and mastery of ecosystem concepts. *Tadris: Jurnal Keguruan dan Ilmu Tarbiyah, 5*(1), 27-41. https://doi.org/10.24042/tadris.v5i1.5943

Hartini, R. F., & Qohar, A. (2018). Pemahaman konsep dan keterampilan proses sains melalui inkuiri terbimbing berbasis lingkungan pada materi ekosistem. *Jurnal Pendidikan*, *3*(9), 1168–1173. https://doi.org/http://dx.doi.org/10.17977/jptpp.v3i9.11531

Henriksen, D. (2014). Full STEAM ahead : Creativity in excellent STEM teaching practices full *The STEAM Journal*, *1*(2). https://doi.org/10.5642/steam.20140102.15

Indriani, D., & Mercuriani, I. S. (2019). Experiential learning model with mind mapping on fungi: how to improve science process skills?. *Biosfer: Jurnal Pendidikan Biologi, 12*(2), 223-237. https://doi.org/10.21009/biosferjpb.v12n2.223-237

Juhji, J., & Nuangchalerm, P. (2020). Interaction between science process skills and scientific attitudes of students towards technological pedagogical content knowledge. *Journal for the Education of Gifted Young Scientists, 8*(1), 1-16. http://dx.doi.org/10.17478/jegys.2020.XX

Kennedy, T. J. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246–258. Retrieved from https://files.eric.ed.gov/fulltext/EJ1044508.

Kristiani, E., Ristanto, R. H., & Lisanti, E. (2020). Exploring gender-based biological concepts: an analysis of bilingual secondary school students. *Biosfer: Jurnal Pendidikan Biologi, 13*(1), 1-13. https://doi.org/10.21009/biosferjpb.v13n1.1-13

Kurniawan, D., Irawati, M. H., & Rohman, F. (2015). Pengembangan perangkat pembelajaran ekosistem dan pencemaran lingkungan berbasis inkuiri serta pengaruhnya terhadap kemampuan berpikir kritis, pemahaman konsep, dan sikap siswa kelas X SMA. *Jurnal Pendidikan Sains*, *3*(3), 137–148. http://dx.doi.org/10.17977/jps.v3i3.8124

Laboy & Rush, D. (2010). Integrated STEM education through project based learning. Retrieved from https://studentsatthecenterhub.org/resource/integrated-stem-education-through-project-based-learning

Lidi, M. ., & Daud, M. . (2019). Identifikasi materi lokal kawasan gunung iya sebagai sumber belajar biologi di kota Ende Maria. *Pancasakti Science Education Journal*, *4*, 97–105. https://doi.org/10.24905/psej.v4i2.1399

Lou, S.J., Chou, Y.C., Shih, R.C., & Chung, C.C.(2016). A study of creativity in steamship-derived STEM project based learning. *EURASIA Journal of Mathematics, Science and Technology*. 1305-8223. Retrieved from https://eric.ed.gov.id

Made, N., Suranti, Y., & Sahidu, H. (2016). Pengaruh model project based learning berbantuan media virtual terhadap penguasaan konsep peserta didik pada materi alat-alat optik. *Jurnal Pendidikan Fisika Dan Teknologi*, *II*(2), 73–79. http://dx.doi.org/10.29303/jpft.v2i2.292

Maghfiroh, N., Susilo, H., & Gofur, A. (2016). Pengaruh project based learning terhadap keterampilan proses sains siswa kelas X SMA Negeri Sidoarjo. *Jurnal Pendidikan*, *1*(8), 1588–1593. Retrieved from https://media.neliti.com/media/publications/210108.

Maradona. (2013). Analisis keterampilan proses sains siswa kelas XI IPA SMA islam Samarinda pada pokok bahasan hidrolisis melalui metode eksperimen. prosidium seminar nasional kimia 2013, 62-70. Retrieved from http://jurnal.kimia.fmipa.unmul.ac.id/index.php/prosiding/article/view/8

Misdar, M. (2018). Mengkritisi faktor -faktor kegagalan akademik siswa dalam belajar. *Jurnal PAI Raden Patah*. *4* (2). Retrieved from https://jurnal.radenpatah.ac.id

Mulyani, L. (2014). Pengaruh pembelajaran berbasis proyek terhadap penguasaan konsep dan keterampilan proses sains siswa kelas X pada materi keanekaragaman tumbuhan biji. *Prosiding Mathematics and Sciences*, 299–306. Retrieved from http://prosiding.upgris.ac.id/index.php/masif2014/masif2014/paper/view/447/396

Na'imah, N. J., Wardani, S., & Supartono. (2015). Penerapan pembelajaran berbasis proyek berbantuan e-learning. *Jurnal Inovasi Pendidikan Kimia*, *9*(2), 1566–1574. Retrieved from https://journal.unnes.ac.id/nju/index.php/JIPK/article/view/4824

Nurhayati, A., Panjaitan, R. L., & Djuanda, D. (2016). Penerapan model pembelajaran inkuiri untuk meningkatkan hasil belajar siswa pada materi gaya gesek. *Jurnal Pena Ilmiah*, *1*(1), 131–140. Retrieved from https://ejournal.upi.edu/index.php/penailmiah/article/view/2944/1973

Nworgu, L. N., & Otum, V. V. (2013). Effect of guided inquiry with analogy instructional strategy on students acquisition of science process skills. *Journal of Education and Practice*, *4*(27), 35–41. Retrieved from https://www.iiste.org/Journals/index.php/JEP/article/view/9880

Ongowo, R. O., & Indoshi, F. C. (2013). Science process skills in the Kenya certificate of secondary education biology practical examinations. *4*(11), 713–717. https://doi.org/10.4236/ce.2013.411101

Özer, D. Z., & Özkan, M. (2012). The effect of the project based learning on the science process skills of the prospective teachers of science. *Journal of Turkish Science Education*, *9*(3), 131–136. Retrieved from https://media.neliti.com/media/publications/120553.

Quigley, C. F., Herro, D., & Jamil, F. M. (2014). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics*, *117*, 1–12. Retrieved from http://scholar.google.com/citations/7VC7NHoAAAAJ

Rahayu, A. H., & Anggraeni, P. (2017). Analisis profil keterampilan proses sains siswa sekolah dasar di Kabupaten Sumedang. *Jurnal Pesona Dasar*, *5*(2), 22–33. Retrieved from http://www.jurnal.unsyiah.ac.id/PEAR/article/view/8847

Ristanto, R. H., Zubaidah, S., Amin, M., & Rohman, F. (2018). The potential of cooperative integrated reading and composition in biology learning at higher education. *International Journal of Educational Research Review*, *3*(1), 50-56. https://doi.org/10.24331/ijere.376727

Roberts. (2012). A justification for STEM education. *Technol.Eng.Teach*, *71*(8), 1–5. Retrieved from https://www.iteea.org/86478

Rustaman, N. Y. (2003). *Strategi belajar mengajar biologi.* Jurusan Pendidikan Biologi. FPMIPA. Universitas Pendidikan Indonesia

Sabara, E. (2016). Keefektifan google classroom sebagai media pembelajaran. *Prosiding Seminar Nasional Lembaga Penelitian Universitas Negeri Makassar*, 122–125. Retrieved from https://www.ojs.unm.ac.id/semnaslemlit/article/viewFile/8256/4767

Siwa, I. B., Muderawan, I. W., & Tika, I. N. (2013). Pembelajaran kimia terhadap keterampilan proses sains ditinjau dari gaya kognitif siswa. *Ejournal Pasca Undiksha*, *3*(3), 1–13. Retrieved from https://ejournal-pasca.undiksha.ac.id/index.php/jurnal_ipa/article/view/794

Smith, J. K., Swaminathan, S., & Schellenberg, E. G. (2015). Arts education , academic achievement and cognitive ability. *The Cambridge Handbook of the Psychology of Aesthetics and the Arts*, Cambridge University Press, 364–384. https://doi.org/10.1017/CBO9781139207058.018

Sugiono. (2012). *Metode penelitian kuantitatif, kualitatif dan R&D*. Bandung: Alfabeta

Sujana, A. (2014). *Pendidikan teori dan praktik*. Bandung:Rizkqi Press.

Tinio, P. P. L., Smith, J. K., Swaminathan, S., & Schellenberg, E. G. (2015). Arts education , academic achievement and cognitive ability. *The Cambridge Handbook of the Psychology of Aesthetics and the Arts*, Cambridge University Press, 364–384. https://doi.org/10.1017/CBO9781139207058.018

Treacy, D. J., Sankaran, S. M., Gordon-messer, S., Saly, D., Miller, R., Isaac, R. S., & Kosinski-collins, M. S. (2011). Implementation of a project based molecular biology laboratory emphasizing protein structure – function relationships in a large introductory biology laboratory course. *CBE-Life Sciences Education*, *10*, 18–24. https://doi.org/10.1187/cbe.10-07-0085

Tsaniyyah, D., Marianti, A., & Isnaen, W. (2019). Keterampilan proses sains siswa pada pembelajaran materi sel dengan model problem base learning berbantuann tutor sebaya. *Jurnal Phenomenon*, *09*(1), 21–35. Retrieved from https://journal.walisongo.ac.id/index.php/Phenomenon/article/view/3229

Tseng, K., Chang, C., Lou, S., & Chen, W. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *Spriner*, (162), 87–102. https://doi.org/10.1007/s10798-011-9160-x

Torkar, G. (2019). *Students ' attitudes toward forest ecosystem services , knowledge about ecology , and direct experience with forests*. *37*. https://doi.org/10.1016/j.ecoser.2019.100916

Utomo, A. P., Hasanah, L., Hariyadi, S., & Narulita, E. (2020). The effectiveness of steam-based biotechnology module equipped with flash animation for biology learning in high school. *International Journal of Instruction,* *13*(2), 463-476. https://doi.org/10.29333/iji.2020.13232a

Wijanarko, A. G., Supardi, K. I., & Marwoto, P. (2017). Keefektifan model project based learning terbimbing untuk meningkatkan keterampilan proses sains dan hasil belajar IPA. *Journal of Primary Education*. *6*(2). https://doi.org/10.15294/JPE.V6I2.17561

Wilson, B. & Hawkins, B. 2019. Art and Science in a Transdisciplinary Curriculum. In Judson, G. & Lima, J. (Eds). *CIRCE Magazine: Steam Edition.* Retrieved from http://www.circesfu.ca

Wulandari, F. E. (2016) Pengaruh pembelajaran berbasis proyek terintegrasi STEM untuk melatih keterampilan proses mahasiswa. Jurnal Pedagogia. Retrieved from http://www.ojs.umsida.ac.id

Yorek, N., Ugulu, I., Sahin, M., & Dogan, Y. (2010). A qualitative investigation of students ' understanding about ecosystem and its components. *Natura Montenegrina*. *9*(3), 973–981. Retrieved from http://kisi.deu.edu.tr/userweb.

You, H. S. (2017). Why teach science with an interdisciplinary approach : History , trends , and conceptual frameworks. *Journal of Education and Learning*, *6*(4), 66–77. https://doi.org/10.5539/jel.v6n4p66

Zeidan, A. H., & Jayosi, M. R. (2015). Science process skills and attitudes toward science among palestinian secondary school students. *World Journal of Education*, *5*(1), 13–24. https://doi.org/10.5430/wje.v5n1p13

Zeitoun, S., & Hajo, Z. (2015). *Investigating the science process skills in cycle 3 national science textbooks in Lebanon*. *3*(3), 268–275. https://doi.org/10.12691/education-3-3-3

Zubaidah, S. (2019). STEAM (science, technology, engineering, arts, and mathematics): Pembelajaran untuk memberdayakan keterampilan abad ke-21. Seminar Nasional Matematika dan Sains. Indramayu: Universitas Wiralodra, 1–18. Retrieved from https://www.researchgate.net/publication/336065211.