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Does STEM-project based learning improve students' literacy as scientific competencies?

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ABSTRACT

Twenty-first-century skills impact educational reform centered on science, technology, engineering, and mathematics (STEM). Middle schools specifically apply STEM to improve students' science skills. Several literature studies show the success of STEM in improving student competence. The effect of STEM-PjBL on the science competencies of grade X students will be specifically explored in this study. The sample consisted of 60 high school students divided into an experimental class (n=30) and a control class (n=30). The posttest-only control group design was adopted in this study. STEM-PjBL learning with reproductive system material was implemented in the experimental class (n = 30) for two weeks, and lecture model learning was implemented in the control class. A total of 60 randomly selected high school students were involved in this study. Quantitative data were processed using Microsoft Excel. Hypothesis testing with normality and homogeneity tests was followed by a *t-test* because the data were normally distributed and homogeneous. This study reveals: (1) The STEM-PjBL model affects student competence. (2) In practical-based materials, the integration of STEM in PBL is proper. (3) Based on the analysis of the STEM-PjBL instrument, the experimental group outperformed the control group on the post-test results. Learning with the systematic STEM-PjBL model has a significant influence on students' science competence.

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INTRODUCTION

Over the last few decades, teachers' and students' literacy skills have become perceived by virtually every school and higher education worldwide. The literacy skills problem has long been a focus of discussion and debate in various media. Students' literacy skills are essential to establishing learning behavior. Organization for Economic Cooperation and Development (2015) shows that more than 10 million students in the OECD countries (Organization for Economic and Cultural Development) have low literacy skills. Compared to the year 2009, Science literacy Skills did not show significant progress (≤ 2%). Indonesia became one of the top-ranked countries (level 1) for Science literacy Issues (OECD, 2019).

International efforts and the Indonesian government have seen a curriculum change that emphasizes reading as a tool for problem-solving and completing specific tasks (OECD, 2019). Low reading ability in Indonesia is a serious problem today. The education system, curriculum, models and methods of learning, facilities, and learning facilities are the most influential factors (Latip & Permanasari, 2015). The scientific study of the curriculum in Indonesia (K13) has been designed and focused on selecting learning models following scientific approaches. The Learning Model covers Project-Based Learning (PjBL), Problem-Based Learning (PBL), and Discovery Learning (DL) (Afriana et al., 2016), TGT type cooperative learning model (Rachmawati & Setyaningsih, 2014).

Since the late 1960s, PBL was designed and developed to help struggling students integrate and apply the knowledge learned in the classroom in their lives (Billiark et al., 2014). The large number of pedagogical assignments given to students is a factor causing these difficulties. The PBL model is seen as a more authentic learning model because students are given full responsibility for independent learning through a collaborative approach (Mustofa et al., 2018). Putri et al. (2020) report that was improving students' critical thinking skills through STEM integrated PjBL learning (STEM-PjBL) is more significant than PjBL alone learning. Students also respond well to the application of STEM-PjBL in learning. According to Ariyatun & Octavianelis (2020), the STEM-PjBL model also significantly influences students' critical thinking skills. This integration has improved learning outcomes, literacy skills, and collaboration (Maulana, 2020).

STEM-PjBL could complement each other because student-based learning is expected to master the materials by making their products/ideas. STEM-PjBL models are essential for students to brainstorm. This model can help students produce ideas with pedagogical techniques to build a team to develop shared knowledge. The STEM-PjBL model group dynamics will serve as incubators when completing work together and creating their creative solutions. In STEM-PjBL, the product or idea generated the students' group by developing the team's planning and redesign process to produce the product. The STEM-PjBL model trains the students' creative ability to relate to four science disciplines to have a deep insight and experience in resolving global problems (Muharomah, R, 2018). Teachers who adopt STEM-PjBL can experience the development of professional experience. STEM-PjBL will require teachers to design high-quality learning activities.

In adopting STEM-PjBL, it is worth considering the linkage between learning objectives, assessment, and student learning process to align the teaching, learning, and assessment (Cindy & Hmelo-Silver, 2019). Many schools adopt STEM-LBL by establishing a Professional Learning Community (PLC). PLC formation provides a discussion of roles and responsibilities, determination of norms, and setting expectations for all group members. A PLC can be essential and very productive, but sometimes PLCs have their stakeholders. STEM-PjBL requires an entirely new perspective on what is meant by judgment.

As an integral component of the STEM-LBL, the assessment does not determine the student's success or failure but holds the project components together to spur students' motivation to study (Eccles & Wang, 2016). In the STEM-PjBL assessment, the teacher should focus on the formative assessment of the learning process (Ashcraft, 2002). Demographic and mediation factors show that self-learning has a very significant contribution to predicting values among respondents. One of the disadvantages of STEM-PjBL is less structured because each group must organize their tasks, time, and materials. However, collaborative skills among students can establish in this process. Students will be accountable for their learning process.

Concerning Literacy, teachers often find obstacles in using content literacy at an early stage. Not a few teachers assume that Literacy is an integral part of the content area. Teachers argue that coaching and collaboration are critical to content literacy development (Cantrell, 2009). Science is one part of content literacy that is still a debate and study in teaching. Soft science literacy skills in developing countries such as Indonesia are still a warm issue to investigate. Educators have not yet understood the proper concrete steps to improve student science literacy. The development of science literacy skills in students with the STEM-PjBL model is seen as a step to be reported. Some studies have positively influenced STEM integrated learning on Student learning Outcomes (Miftahuzzakiya, 2018). Afriana et al. (2016) mention that science literacy skills can be increased after using the STEM-PjBL model in technology and design.

The STEM-PjBL model can be done online using cloud computing that educators and learners can access in today's digital age. This online STEM-PjBL learning can improve collaboration, planning, and communication between students and teachers (Cakiroglu & Erdemir, 2018). Although STEM-PjBL models have proven to have a good influence on improving science literacy, to the extent that we know the effectiveness of STEM-PjBL models on the science competency aspect is still a piece of information (Permanasari, 2016). Based on survey results at several secondary schools in Banten province, Indonesia, the STEM-PjBL model is rarely implemented in the biological learning of reproductive system materials (UNEJ, 2019). The assessment questions that are used to measure learning outcomes are not yet science-based Literacy. Correlate the STEM-PjBL model with students' scientific literacy competence with three indicators, namely explaining scientific phenomena, using scientific evidence, and identifying scientific problems will be revealed in this study. This study was designed to determine the effectiveness of STEM-PjBL learning on aspects of students' science competence. This study's results are expected to motivate educators to use a project-based learning model that STEM-integrated in science learning.

METHODS

Research Design

This experimental learning research was designed to determine the effectiveness of the STEM-PjBL model in changing literacy skills in the aspect of scientific competence. The implementation of the STEM-PjBL model was applied to class 10 reproductive system materials. We adopted a qualitative approach and an actual experiment with a post-test-only control group design for this purpose (Monroe et al., 2016; Syintia et al., 2018).

Participant

The public high school (SMAN) in Banten, Indonesia, is the population of this study. By random sampling, 60 students (28 male and 32 female) from two classes in Cikande, Banten, were determined. The samples taken were considered to meet the criteria for research purposes. This study uses test instruments in the form of science literacy-based scientific competency aspects. This test instrument measures the three competencies of science, which can describe scientific phenomena, use scientific evidence, and identify problems. Biological and material teachers have validated this study's test instruments and tested on learners outside the samples and reliability tested. These excellent and reliable problems can be used to measure Science Literacy and Science competency aspects.

Instrument

The instrument has been validated by a biology teacher and tested on students outside the sample. The test results were analyzed with the reliability test. The science Literacy-based information test instrument consists of 10 items divided into several parts to be grouped into scientific competence. That part is the aspect of explaining the Ilmiah phenomenon as many as four rounds, aspects of using scientific evidence As many as four items, and identifying scientific issues as many as two items. Each question is given a cognitive level from C1 to C5, shown in Table 1. The learners' answers are analyzed based on each aspect of science literacy competence to obtain the percentage of achievement per aspect. The score was obtained for each item with a scale of 100. The post-test calculation is calculated using Microsoft Excel 2019.

Procedure

In this study, the STEM-PjBL model science competency instrument was applied for three weeks. One week before the research was given, we coordinated with the teacher to ensure that the STEM-PBL learning plan on the reproductive system material was ready and correct. The instruments were tested in all groups after the material was finished. Answer questions. The results of the answers are used as the primary data for analysis. We recorded the students' answers in both the control class and the treatment class for comparison.

Table 1.
Grid of Science Literacy Instruments on Aspects of Knowledge

Types of Science Literacy (Science Competency Aspect)	Item Number	Item Equal
Explaining scientific phenomena	1,2,6	3
scientific evidence uses	3,4,5,7,8	5
Identifying Scientific issues	9,10	2

Data Analysis

Scientific literacy skills in the knowledge aspect of students begin with quantitative data processing. Quantitative data were obtained from students' scores by answering the questions on aspects of scientific competence. The score given for each item uses a scale of 100. The final score for participants is calculated using percentages correction in Microsoft Excel 2019. The calculation of percentages correction is carried out using the following formula (Purwanto, 2012):

$$NP = \frac{R}{SM} x \, 100$$

Note:
NP: The percent value sought or expected
R: Raw scores obtained by students
SM: The ideal maximum score of the test in question
100: Fixed number

We performed tests of normality (Table 2) and homogeneity (Table 3) before further analysis (t-test). The calculation of the normality of the distribution in control and experimental classes has a normal distribution, and then the analysis prerequisite test is continued with the homogeneity test. The results of the homogeneity test above show that $F_{count} < F_{table}$ (1 < 2.423). This result tells that both of the data were homogenous.

Table 2.
Normality test results

Group	N	$\bar{x}$	SD	Db	X^2_{hit}	X^2_{tab}	Decision
Control	30	62.13	8.82	3	6.75	11.34	Normal
Experiment	30	68.73	8.79	3	4.17	11.34	Normal

Table 3.
Homogeneity test results

Group	N	SD	V	F_{count}	F_{table}	Decision
Control	30	8.82	77.79	1	2.423	Variance Homogeny
Experiment	30	8.79	77.26			

RESULTS AND DISCUSSION

The results outlined in this study are the post-test results of both classes (control and treatment classes) show in Table 4, shows the post-test result data in the lower control class compared to the experiment group with an average of 62.30 values. In a more active student experiment group to gather relevant information on the human reproductive system and perform project creation, the student control group focuses on capturing educators' information during the learning process. The control class that implements the lecture model has a mastery of science literacy is lower in science than the experimental class applied by the STEM-PjBL model. The percentage of test result increase in each aspect of the competency is shown in Figure 1.

Table 4.
Posttest Result on Control and Experiment Class

Group	N	SD	$\bar{x}$	Min. Score	Max. Score
Experiment	30	8.79	68.67	54	88
Control	30	8.82	62.30	42	88

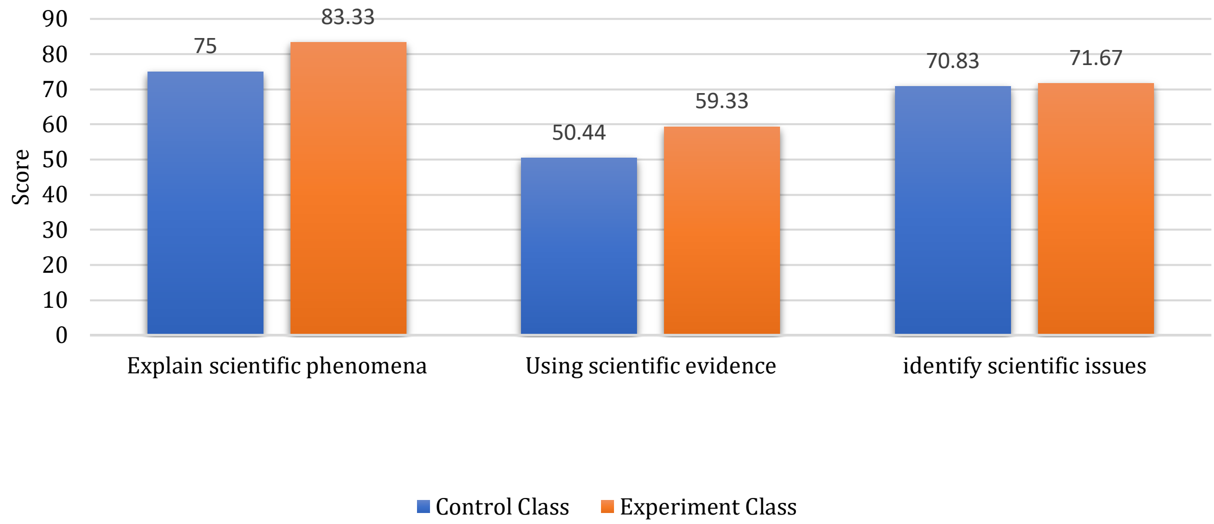

Figure 1. Test result percentage of control and experiment class

Data analysis shows that science literacy skills in science competency aspects using the STEM integrated PjBL model have a higher proficiency level than lecture learning models. It can be seen from the average value of the control class of 62.30, while the average value in the experimental class is 68.73. The test results of normality and homogeneity in both class ordinary and homogenized distribution. The hypothesis test uses a parametric test using test-T. The hypothesis test results showed an influence on the PjBL STEM model implementation (Table 5).

Table 5.
T-test results on hypothesis testing

Group	$\bar{X}$	T_{count}	t_{table}	Decision	Statistical Hypothesis
Control	62.13	3.00	2.66	Significantly Different	H_0 is rejected, H_1 is accepted
Experiment	68.67				

Standard deviation determines the spread of data in the sample. If the data result's standard deviation value is equal to zero, then all the average values of that data are the same. Conversely, if the standard deviation value is high, the individual data is far from average. The experimental class has a lower standard deviation than the control class based on the standard deviation results. The experiment class data results show that the experimental class's average distribution is better and uniformly close to zero (the same distribution and capacity). The ability of science literacy aspects of the students' competency measured in this study has three competencies: explaining scientific phenomena, using scientific evidence, and identifying scientific issues. This study shows that explaining the scientific phenomenon has the highest value of experimental class or control.

This study's scientific phenomenon is measured by three indicators describing or interpreting phenomena and predicting changes, applying scientific knowledge in the phenomenon given, and identifying the exploitation and Appropriate predictions (Sastrika et al., 2013). Project-based learning models applied to learners can better remember and apply appropriate knowledge to learners who acquire lecture learning models. Students with PjBL applied model have a better understanding of the concept (Sari et al., 2017). This opinion is reinforced with the results of Docktor & Mestre (2014), which says that project learning can improve conceptual understanding. Project-based learning makes students have a better conceptual understanding. This learning model has a learning step discovery. This step combines collecting relevant information to design a project, then applying product planning or solutions to solve the problem and displaying the results of activities done to obtain the desired knowledge through the presentation.

The ability of science literacy aspect competency in using this scientific evidence measured two indicators IE (1) interpret scientific evidence and draw conclusions (2) give reasons to support and reject conclusions (Furi et al., 2018). The outcome of the class percentage of experimentation was quite capable of interpreting data and drawing proper conclusions. The control class acquiring a lecture learning model has a lower percentage value. This study shows that classes using the Project-Based Learning learning model can use scientific evidence. The experimental class can distinguish between arguments based on scientific evidence, assumptions, and other considerations and evaluate arguments based on scientific evidence. Project-based learning models require learners to demonstrate their knowledge by producing products/ideas and presenting them in class. Robinson (2013), in his research, says that students in project-based learning are allowed to use their knowledge to create a product after the investigation to solve the problem that is sourced from real life.

Project-based learning encourages learners to investigate and think critically about using their knowledge to solve problems. Data shows that learners who use project-based learning can identify problems better than learners who use conventional learning. Following Wijayanti & Khusnul (2018), research states that project-based learning has a learning phase to incorporate the knowledge owned with the problem to solve the problem. Well-developed Literacy can help students think critically, logically, creatively, and have ideas in solving everyday life problems. A person can have literacy skills proven by the individual to analyze and explain with scientific evidence to be drawn (Gormally et al., 2009).

CONCLUSION

The STEM-Integrated Project Based Learning (PjBL) learning model affects all indicators of students' scientific literacy competence. Researchers found the inability of students to do more creative projects because students were more motivated to imitate the examples of projects given by the researchers. Although the results of the study were satisfactory, students could not generalize due to several limitations. The number of each meeting is less than 2 hours; inadequate facilities; the lack of creativity of students in doing projects is an obstacle in this research. Further improvement is needed, especially in the selection of research sites. Schools with better facilities are expected to improve the results of similar studies in a more positive direction.

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