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STEAM-Project-Based Learning: A Catalyst for Elementary School Students' Scientific Literacy Skills

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Abstract: The need for early comprehension of scientific concepts in elementary school students is crucial. However, studies have indicated that some students lack a fundamental understanding of such concepts, highlighting the importance of effective teaching methods to improve scientific literacy at an early age. Therefore, this study aimed to determine the ability of Project-Based Learning in Science, Technology, Engineering, Art, and Mathematics (STEAM-PjBL) to improve students' scientific literacy, knowledge, and application of foundational scientific principles. A quasi-experimental methodology was employed, involving 22 female and 26 male fourth-grade elementary school students as participants. The study administered a Scientific Literacy Test (SLT) treatment to the students, followed by unpaired and paired t-tests to examine the impact of the STEAM-PjBL model on their scientific literacy skills. The results showed that STEAM-PjBL improved students' scientific literacy skills significantly more than traditional instruction. The experimental group outperformed the control group in the post-test, indicating the effectiveness of STEAM-PjBL. Therefore, the study recommends the adoption of the STEAM-PjBL model by elementary school teachers to improve students' understanding of fundamental scientific concepts.

Keywords: *Elementary education, project-based learning (PjBL), scientific literacy, STEAM.*

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Introduction

In the 21st century, scientific literacy has become a vital skill for students to possess. Being competent in science-related courses is crucial for students to be considered scientifically literate (Suryanti et al., 2018; Udompong & Wongwanich, 2014; Widodo et al., 2020; Yuliana et al., 2021). According to Norris and Phillips (2003), scientific literacy skills connect science education to the curriculum in order to ensure students acquire relevant knowledge such as actions and contemporary science education themes. This led to the definition of scientific literacy skills as the ability to utilize knowledge of the nature of science to recognize and identify social problems, create good decisions, and contribute to society (Azura et al., 2021; Bauer & Booth, 2019; Putra et al., 2016; Suryanti et al., 2018; Suwono et al., 2021; Yuliana et al., 2021). Moreover, these skills enable information management, communication, and collaboration capabilities (Ke et al., 2021).

The Organization for Economic Co-operation and Development (OECD) has reported that critical scientific literacy skills involve asking and answering important questions, drawing valid conclusions from facts, understanding how natural and human-caused events interact, and making decisions based on available and reliable information (OECD, 2019). Additionally, the scientific literacy evaluation system developed by PISA is based on three pillars, namely, the ability to identify scientific issues, describe scientific occurrences, and apply scientific evidence (Al Sultan et al., 2021; Bybee et al., 2009; OECD, 2019). This study defines scientific literacy as the process of comprehending and applying scientific information to identify concerns and form opinions about natural phenomena.

Several studies have been conducted on scientific literacy (Belland et al., 2017; Holzberger et al., 2014),, which has become the primary learning objective at all education levels, including elementary schools (Yuliana et al., 2021). However, the International Science Education Community has reported that the majority of people still lack 21st-century scientific literacy skills (Faisal & Martin, 2019). This is further supported by the PISA 2018 report, which revealed low

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scientific literacy skills in several nations, including Indonesia, ranking 72nd out of 77 nations studied (Azura et al., 2021; OECD, 2019).

Moreover, various studies have observed that students in Indonesian elementary schools have low levels of scientific literacy skills (Azura et al., 2021; Putra et al., 2016; Suryanti et al., 2018; Suwono et al., 2021; Widodo et al., 2020). A similar trend was also reported in Thailand due to their learning approach being not competitive internationally (Udompong & Wongwanich, 2014). Furthermore, Mun et al. (2015) found that Korean high school students lacked the confidence to apply their knowledge to real-world situations, which affected their ability to solve problems.

Students' scientific literacy skills can be influenced by the educational method, school resources, and their background (Holzberger et al., 2014). The reasons for the low rate reported by students have been discussed by educators. Demirel and Caymaz (2015) noted that the trend can be changed through the assistance of national education. Meanwhile, Sarkar and Corrigan (2012) discovered that the majority of educators continued to have difficulty in implementing effective teaching strategies (Al Sultan et al., 2021; Azura et al., 2021; Jatmiko et al., 2018; Suryanti et al., 2018; Widodo et al., 2020; Yuliana et al., 2021). This is the reason for the implementation of the STEAM approach in the recent interconnected world to improve scientific literacy skills.

STEM-based education is an interdisciplinary learning approach observed to have become the goal of several nations in recent decades (Belbase et al., 2022; Irwanto et al., 2022; Lie et al., 2020; Young et al., 2018). Moreover, the Ministry of Education, Science, and Technology in South Korea proposed art as the fifth transdisciplinary topic under Science, Technology, Engineering, Art, and Mathematics (STEAM) in 2011 (Kang, 2019). This approach was used to serve as a unit of learning involving the application of new technology, design thinking, and inquiry (Stroud & Baines, 2019). According to DeJarnette (2018), STEAM can be used to assist children to integrate multiple disciplines needed to improve their learning experience as well as to allow them to investigate, ask questions, or practice innovative skills. The application of the STEAM approach in project-based learning has five steps which include connecting, planning, developing, collaborating, and transferring (Hadinugrahaningsih et al., 2017).

The STEAM concept is expected to improve conceptual understanding and literacy skills and this means scientific knowledge can be used to solve the world's environmental problems (Kang, 2019; Queiruga-Dios et al., 2021; Yakman & Lee Hyonyong, 2012). This has led to the global prioritization of STEAM learning as a way to prepare students for future challenges (Bati et al., 2018; Peppler & Wohlwend, 2018; Quigley et al., 2020). Several studies were observed to have been conducted on STEAM education in the world in the past ten years (Bati et al., 2018; Diego-Mantecon et al., 2021; Erol et al., 2023; Quigley et al., 2020). This form of education offers several benefits such as the integration of STEAM instruction in schools to explore students' abilities, improve collaboration with peers, emphasize technology in the learning process, improve literacy, and ensure global competitiveness (Diego-Mantecon et al., 2021; Gettings, 2016; Land, 2013; Tenhovirta et al., 2022). However, many teachers and science educators have not prioritized and identified the measures required to integrate effective STEAM learning (Bati et al., 2018). This can cause a global decline in STEAM education. For example, Korean students were discovered to have a low interest in science (Yakman & Lee, 2012), demand different professions apart from scientists and engineers, and continue to adhere to a subject-based education (Kim & Lee, 2016). Another study also showed that the interest of the younger generation in Japan in science and technology was declining (Matsuura & Nakamura, 2021).

Studies also showed that children with STEAM knowledge are scientifically literate (Adriyawati et al., 2020; Belbase et al., 2022; Kang, 2019). Meanwhile, the application of this education method requires a suitable learning model to maximize its benefits. This led to the introduction of Project-Based Learning (PjBL) as a good reference for this purpose (Adriyawati et al., 2020; Gettings, 2016; Kang, 2019; Queiruga-Dios et al., 2021; Vicente et al., 2021). It is pertinent to note that STEAM-integrated learning can improve students' knowledge application. This is mainly because PjBL enables students to investigate and build learning activities, collaborate on projects, and produce a result (Aránguiz et al., 2020; C.-H. Chen & Yang, 2019; Kaldi et al., 2011; Susanti et al., 2019).

The PjBL (Project-based Learning) method is centered around the idea of using projects as the core of the teaching process, where concepts, content, and standards are applied (Martinez, 2022). Teachers are responsible for ensuring that students actively participate in creating innovative projects (Adriyawati et al., 2020; Chang & Yen, 2021; Vossen et al., 2021). Furthermore, previous studies have shown that the application of PjBL can improve students' scientific literacy skills (Adriyawati et al., 2020; Muhibbuddin et al., 2020; Putra et al., 2016).

The PjBL method enables students to solve problems using the scientific method's procedure and time focus (Miller & Krajcik, 2019; Ulger, 2018). Teachers play the role of overseers in the process of developing projects using real-world materials obtained through PjBL (Beier et al., 2019; Bell, 2010; Chang & Yen, 2021). It is important to note that several methods are available to collect data, study, and analyze information before committing to a final product (Kaya & Elster, 2018). To develop a strong science foundation, children require meaningful and hands-on science experiences (Dori et al., 2018). Identifying scientific phenomena, planning and executing scientific studies, and interpreting scientific data and evidence are the critical steps required to form scientific conclusions (Chiu & Lin, 2019). PjBL makes this process easier by providing empirical methods that can be implemented in the classroom. Moreover, enjoying science and scientific inquiry is essential for students to develop scientific literacy. PjBL fosters independence and originality in the classroom, providing students with real-world experience in different content areas (Lestari et al., 2018). This approach has been reported to enhance students' motivation and enjoyment of science, leading to better learning outcomes (Lestari et al., 2018; Muhibbuddin et al., 2020). PjBL has also been reported to improve students' basic scientific knowledge (Afriana et al., 2016; Juleha et al., 2019).

The PjBL approach teaches several essential strategies in the 21st-century (Bell, 2010), while STEAM is more of a grand strategy aimed at combining broader disciplines (Belbase et al., 2022). Although the attributes of both concepts are similar, STEAM-PjBL focuses more on the design process and serves as a systematic approach to finding appropriate solutions to problems (Capraro et al., 2013).

The STEAM-PjBL instructional model can be used to assist students in comprehending the concepts of science in the classroom. It can also be used to improve the scientific literacy skills of elementary school students through the involvement of educators from different fields in designing the lesson plan (Gettings, 2016; Liao, 2016; Queiruga-Dios et al., 2021; Yakman & Lee Hyonyong, 2012).

Several studies showed the ability of PjBL learning to enhance STEAM but none was found to have focused on the improvement of scientific literacy skills, especially specifically among Elementary School students (Adriyawati et al., 2020; Gettings, 2016; Queiruga-Dios et al., 2021; Vicente et al., 2021). It was also discovered that the STEM learning model improved students' scientific knowledge and application (Rochman et al., 2019) but the "art" aspect was not included, and the study did not focus on Elementary School students. Therefore, this study discussed these theoretical and practical gaps using one line of inquiry: Is there a significant difference in the scientific literacy student assessments after the application of STEAM-PjBL?

Methodology

Study Design

This study examined the difference in the scientific literacy skills of two groups including the experimental group that received treatment and the control group without treatment using a quasi-experimental design with pre- and post-tests (Dimitrov & Rumrill, 2003). The treatment applied was the STEAM-PjBL model for the experimental group and the conventional learning method for the control group, after which the average post-test scores were compared. The quasi-experimental characteristics used are presented in the following Table 1 (Creswell & Poth, 2018).

Table 1. Quasi-Experimental Pretest-Posttest Design

Class	Pre-test	Treatment	Posttest
Experimental	SLT1	STEAM- PjBL	SLT2
Control	SLT1	Conventional Learning	SLT2

Sample and Data Collection

The respondents used were selected through a purposive sampling method. It was discovered from the school administrative records that there were multiple fourth-grade classes in public Elementary Schools with students aged between 10 and 11 years old and taught by teachers having the same qualifications and socioeconomic status. A pre-test was applied in all four classes to determine students' intelligence and knowledge, and the findings showed that they all had almost similar abilities. Therefore, the experimental group was made of 24 students consisting of 10 females and 14 males while the control group had 24 students consisting of 12 females and 12 males. This means both classes had the same teacher and the students had comparable ages, genders, intelligence, knowledge, and socioeconomic status, thereby indicating the absence of demographic issues.

The experimental group was taught using a STEAM-PjBL approach while the control group was trained using conventional methods, and all students were instructed by expert instructors. This study was conducted in September and October 2022, which was an even academic year.

The SLT was designed based on the PISA-OECD 2019 framework and applied to measure three skills which include describing scientific phenomena, evaluating and conducting study, and understanding data and evidence. It is important to note that each statistic had four SLT questions and they were all proven and tested empirically. Moreover, three experts including two senior lecturers and one experienced teacher also checked the product for accuracy. Cronbach's alpha was also used to assess the internal consistency and it was discovered that the values for each scale were at or above the standard value. Furthermore, 83-point subscales were used to characterize the scientific phenomena. This was necessary because the focus in 1982 was on evaluating and planning scientific studies. Another important point was that .84 and .83 were used for data interpretation and scientific evidence, respectively, in order to ensure the validity and reliability of the SLT developed in calculating the scientific literacy of the students. The Scientific Literacy Test (SLT) Questions focus on a) defining scientific phenomena, (b) evaluating and designing scientific studies, and (c) analyzing data and scientific evidence.

Table 2. Scientific Literacy Test Examples (SLT) Questions

(a) SOLAR PLANE FLYING IN A SHADOUT DAY

Pontianak, CNN Indonesia -- The Pontianak youth community flew a solar-powered drone. The Unmanned Aerial Vehicle (UAV) or solar-powered unmanned aircraft was claimed to be the first in Indonesia. "We make our own planes, not assemble them, except for the solar cells that we import from China", said Borneo Skycam CEO, Toni Eko Kurniawan, on Wednesday (21/3) when he was met at the 2018 Pesona Culmination Festival.

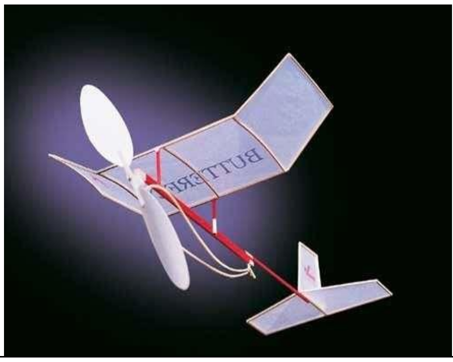
The solar-powered aircraft was called OPIOR 1603 and it was developed by the Borneo SkyCam Community and the Creative Robotic School. Borneo Skycam engaged in drones and mapping while Creative Robotic was a local robotics community.

According to Toni, the aircraft was used alone to retrieve map data by covering an area of 1,000-3,000 hectares at a time. Toni had expected that the capabilities of this aircraft could be further developed to be applied for military purposes. "*It can be used for monitoring national borders or map data retrieval, we also open the door for investors interested in developing this unmanned aircraft project*", concluded Toni.

Source:https://www.cnnindonesia.com/teknologi/20180321202209-199-284873/pesawat-tenaga-surya-terbang-di-hari-tanpa-bayangan

The article shows that the Borneo SkyCam Community and the Creative Robotic School have been able to fly solar-powered unmanned aircraft. Explain the energy changes that occur in a solar-powered drone in simple terms.

The force of gravity will cause all objects that are thrown up to fall back to Earth. How can an airplane fly in the air despite the existence of the Earth's gravitational force?



(b) RUBBER-POWERED PLANE

Rubber-powered planes are miniature planes that can fly using rubber-powered propellers. The plane was produced using light and strong wood to allow beautiful flight and agility in the sky. Rubber was used as the source of propulsion because it was a staple material.

Arya and his team are also working on a rubber-powered aircraft manufacturing project. At the design stage, Arya said that using tan rubber would produce a better and stronger thrust than ordinary rubber bands. If we look closely, what Arya did was actually part of the scientific method known as________.

After going through the stages of planning, manufacturing, and testing the rubber-powered aircraft produced with his team, Arya explained that tan rubber produced a better and stronger thrust than ordinary rubber bands. If we look closely, what Arya did was actually part of the scientific method known as________.

(c) Proposed Avtur Price Reduction

From the picture, what are the factors that differentiate the prices of avtur in Indonesia?

Source: https://www.liputan6.com/bisnis/read/3894428/headline-usulan-harga-avtur-turun-mungkinkah

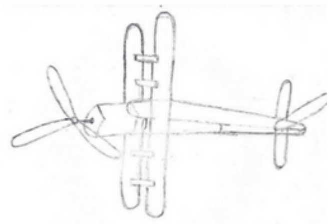
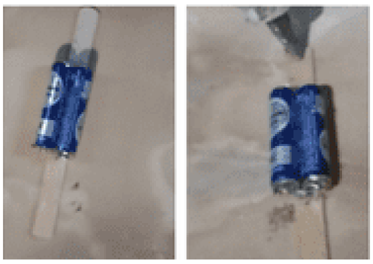
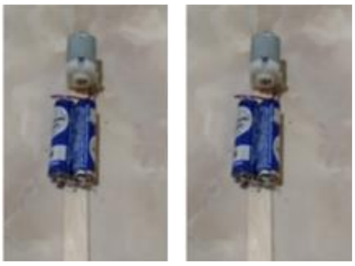
Official approval was received from the school administrators and faculty members before this study was conducted. Moreover, students were provided with an overview of the study objectives, required to take SLT before classes began, and participated in two study sessions. It is important to reiterate that the conventional method was applied to the control group while the STEAM-PjBL approach was used for the experimental group.

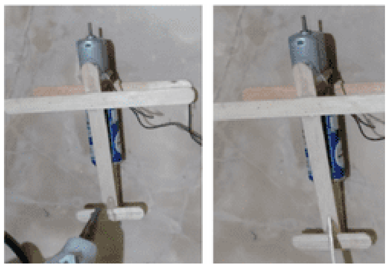
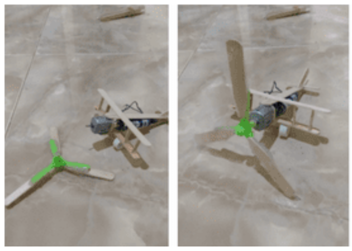
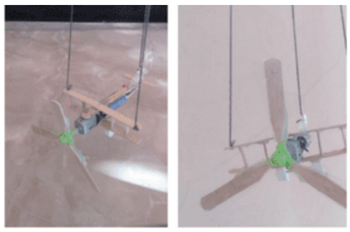
Learning Steps Using STEAM-PjBL: Producing Battery-Powered Airplane (BAPORA)

The Battery-Powered Airplane (BAPORA) was an aircraft powered by batteries and combined with STEAM-PjBL. The STEAM components involved in the project include (a) Science such as Muscle, Gravity, Spring, and Friction Forces as well as Chemical, Light, Motion, Chemical, and Potential Energies, (b) Technology such as the application of YouTube to learn airplane production, the internet to find references, and STEAM project activities document, (c) Engineering through the design of an airplane, sticking techniques and patterns of airplanes, and assembly technique, (d) Arts by creating a nice aircraft through the selection of appropriate colors and shapes as well as the decoration, and Mathematics through the measurement of angles and flat shapes.

Students were able to assess alternative energy sources in constructing the BAPORA using the essay titled "Plane Ticket Prices Rise after the Price of Amenities" and later decided on the alternative energy sources to be used in addition to batteries. They eventually built a three-dimensional BAPORA project.

Table 3. Learning Steps Using STEAM-PjBL

Steps	Instructions	Picture
1	Sketch the plane according to your creativity.	
2	Attach two batteries to an ice cream stick with hot glue.	
3	Connect the dynamo and battery with a cable intermediary properly by soldering it.	

4	Install the switch to turn on the battery on the aircraft.	
5	Install the aircraft frame, including the side and rear wings (with due consideration for the angles formed).	
6	Install the propeller on the front of the dynamo, add pieces of ice cream sticks, and then install the wheels on the bottom of the aircraft by considering the science, engineering, and art aspects.	
7	The battery-powered plane was ready to go. It was, however, threaded on the side of the wing to allow it to fly.	

Data Analysis

The Cronbach alpha value of 0.83 showed that the data were valid and reliable. Moreover, Shapiro-Wilk and Levene's tests were used to determine the data normality and homogeneity, respectively. Independent paired t-tests were also applied to evaluate the effects of the STEAM-PjBL on students' scientific literacy skills and the results were presented in the form of mean, standard deviation, maximum, and minimum scores. Furthermore, T-test was used to compare the mean test results (RQ1) for the experimental and control groups while a paired t-test was applied to examine the scientific literacy scores of the students in the experimental group before and after treatment (RQ2). The 0.20 d > 0.80 and implied a statistically significant effect, therefore, Cohen's d was also used (Cohen, 1992). Inferential analysis was conducted at 0.05 using Statistical Package for the Social Sciences (SPSS) 23.

Findings

The activities of STEAM-PjBL conducted include presenting real-world issues, finding information on alternative solutions, designing projects, working on projects, collecting and analyzing data, and making conclusions. The process in the experimental group was initiated by presenting authentic problems for the students which involved the scarcity and high cost of avtur or aircraft fuel in Indonesia. Students were instructed to list the alternative energy sources that can be utilized to solve the issue. They were also provided with worksheets to record their thoughts. Students discovered that biodiesel and bioavtur has the ability to supplant avtur through the exploration of ICT such as Google, YouTube, e-books, websites, and others.

Teachers later used a Styrofoam miniature airplane as a visual aid. Therefore, students conducted a secondary study and found out that wind, electricity, and batteries (chemistry) were viable alternative energy sources. It is important to note that those in the experimental group constructed a BAPORA (Producing Battery Powered Airplane) project as outlined in Table 3 and made several attempts to improve the aircraft's performance in flight. All the problems encountered necessitated an immediate search for solutions. Meanwhile, students in the control group only learned about alternative energy sources through direct explanations from the teacher and book reading without making any contribution. This meaningless learning experience discouraged students and made it easy for them to forget the concept.

The information-gathering activity conducted by students improved their scientific literacy. Moreover, they were also taught the methods to formulate inquiries in addition to identifying questions, gaining new knowledge, explaining scientific phenomena, and drawing conclusions. The STEAM-PjBL process was discovered to be enjoyable for the students because debated freely, designed the BAPORA projects according to their preferences, described the processes used to enable the BAPORA to fly like an actual airplane, and explained the usefulness of batteries as one of the energy sources to propel the plastic aircraft.

The challenge experienced in this study, particularly during the implementation of the STEAM PjBL, was to ensure the students did not have misconceptions about alternative energy. It was also to make sure every student in the group contribute to the project and did not focus only on making BAPORA projects but also to find solutions to phenomena, identify information and data, and process the data before reaching a conclusion.

The experimental group was observed to have lower pre-test scores than the control group on average. The difference in the scientific literacy level of the two groups was further determined statistically using independent t-tests. The findings showed that there was generally no difference between STEAM-PjBL and conventional teaching (t (48) = -.207, p =.750), as indicated in Table 4. This means all the participants had the same level of exposure to basic science concepts before the learning activities and treatments were implemented.

Table 4. Disparity in Pretest Scores for Treatment and Control Groups

Sub-scales	Groups	N	M	SD	t	p
Explain phenomena scientifically	Control	24	.46	.58	-2.40	.020
	Experimental	24	.87	.61		
Evaluate and design scientific inquiry	Control	24	1.63	.87	-2.67	.010
	Experimental	24	2.25	.74		
Interpret data and evidence scientifically	Control	24	1.58	.72	-202	.841
	Experimental	24	1.62	.71		
All subscales	Control	24	3.67	.217	-.207	.750
	Experimental	24	4.75	.206		

The post-test scores of the experimental group students increased significantly on all scientific literacy subscales after the treatment. Table 5 shows that there is a significant statistical difference between both groups for the post-test. This was indicated by the existence of substantial differences in the means of all measures of scientific literacy skills (p = 0.05). The findings showed that students' scientific literacy skills taught using STEAM-PjBL were better than those taught through conventional methods.

Table 5. Comparison of Posttest Scores for Treatment and Control Groups

Sub-scales	Groups	N	M	SD	t	p
Explain phenomena scientifically	Control	24	.92	.66	-4.048	0.000
	Experimental	24	1.79	.84		
Evaluate and design scientific inquiry	Control	24	2.25	.16	-4.628	0.000
	Experimental	24	3.00	.68		
Interpret data and evidence scientifically	Control	24	1.75	.94	-3.265	0.002
	Experimental	24	2.54	.72		
All subscales	Control	24	4.91	1.76	-.207	0.001
	Experimental	24	7.33	2.23		

The second research question was investigated by comparing the pre-and post-test scores for the two groups using a paired t-test and the findings are presented in the following table.

Table 6. Trends in Students' Mean Standardized Literacy Science Test Scores

Sub-scales	**Paired Differences**		**t**	**df**	**p**	**Cohen's d**
	M	**SD**				
Explain phenomena scientifically	-.68	.624	-7.63	24	.000	9.49
Evaluate and design scientific inquiry	-.68	.776	-6.14	24	.000	12.87
Interpret data and evidence scientifically	-.54	.824	-4.55	24	.000	13.18
All subscales	-1.19	2.24	-15.2	24	.000	15.65

Table 6 shows there was a 1.24 point average increase in the score recorded for the control group from 3.67 to 4.91 while the increment for the experimental group was 2.58 from 4.75 to 7.33. The results also showed that the mean score of the experimental group experienced a statistically significant improvement ($t(24) = -15.23$, $p = 0.000$), and a similar trend was found with all scientific literacy sub-scales ($p < 0.05$). Moreover, both groups improved significantly from the first to the second tests but the Cohen's d rose substantially ($d = 15.65$) for the experimental group. The findings showed that the improvement in the post-test score for the experimental group was more significant than the control group. Therefore, the STEAM-PjBL model improved students' participation in basic science.

Discussion

The results of the post-test indicated a statistically significant difference between the experimental and control groups, with the experimental group scoring higher in general knowledge and scientific literacy assessments. This finding suggests that every activity incorporated into the STEAM-PjBL model contributed to the development of scientific literacy skills among students.

The contribution of each STEAM-PjBL activity to scientific literacy

The activities implemented in the STEAM-PjBL model for this study included presenting real-world issues, researching alternative solutions, designing projects, working on projects, collecting and analyzing data, and drawing conclusions. The results showed a significant improvement in students' abilities in the experimental group, which was attributed to their increased engagement in these activities. By not providing automatic solutions, students were encouraged to search for information independently, review previous readings, and determine relevant answers to real-world problems. Previous studies have noted that solving real-world issues can enhance social and cognitive abilities (Othman et al., 2022) and that students who possess a strong foundation in science can apply critical thinking to scientific problems (Ulger, 2018). This study's findings were also in line with those of Betari et al. (2016), who reported that problem-based instruction enhanced students' scientific literacy skills. Through the application of scientific methods to real-world problems, students were able to discover and implement appropriate solutions (Narut & Supardi, 2019).

In the STEAM-PjBL class, students engaged in reading, studying, and collecting data to develop their project (Diego-Mantecon et al., 2021; Gettings, 2016; Queiruga-Dios et al., 2021). Upon completion of the project, it was discovered that the self-assurance and motivation of the students had increased. This was attributed to their active involvement in problem-solving activities and the development of study strategies for generating answers. Additionally, the STEAM-PjBL class had the effect of increasing students' enthusiasm and inspiring their curiosity towards the subject of science, which in turn led to the acquisition and application of classroom material in real-world situations. These findings are in line with previous studies that have demonstrated the importance of students' motivation in the development of scientific literacy (Susiani et al., 2018; Wahyuni et al., 2018) and the significant influence of the interaction between inspiration and learning models on students' success in science courses (Bagiarata et al., 2018).

Mastery of basic science is an effective way to prepare students for success in various fields (Pertiwi et al., 2018). It has been discovered that projects developed through project-based learning (PjBL) can enhance students' scientific literacy skills (Azura et al., 2021; Gertner et al., 2023). This is because PjBL enables an increase in lesson relevance through student-centered learning, independent study, and material analysis (Kaya & Elster, 2018). In contrast, teacher-led classes do not improve scientific literacy skills (Suryanti et al., 2018; Widodo et al., 2020).

The learning exercise in the BAPORA project was a gas-price workaround that allowed the application of STEAM to link common issues such as energy to scientific principles. The most common form of energy is fossil fuel and its adverse effects have led to the need for sustainable alternatives (Yüksel, 2019). This is the reason students are required to learn about the concept early in their academic careers (Merritt et al., 2019). The project allowed students to gain experience in evaluating and implementing real-world applications of different renewable energy sources.

These findings showed the ability of STEAM-PjBL activities to improve students' scientific literacy skills. The STEAM enhanced the technology employed by students to understand different ideas, while PjBL ensured they have certain products as the learning outputs. This was in line with a previous study that STEM education enabled students to comprehend concepts or knowledge related to science before advancing their understanding through technological means (Budiyanto et al., 2022).

STEAM-PjBL improved scientific literacy test results

The application of STEAM in the context of project-based learning (PjBL) has been found to be highly effective in increasing students' interest and knowledge in science (Adriyawati et al., 2020). This is due to the interdisciplinary nature of STEAM, which provides opportunities for students to learn about a wider range of subjects and apply their knowledge to solve real-world problems (C.-H. Chen & Yang, 2019). Furthermore, the STEAM-PjBL model encourages students to think creatively, as they are encouraged to consider multiple perspectives and engage in problem-solving activities that require innovative solutions.

The results of an independent t-test indicated that students in the experimental group had better scientific literacy skills than those in the control group. This suggests that the STEAM-PjBL approach was more effective in promoting scientific literacy than conventional methods. One reason for this is that the STEAM-PjBL approach encourages students to plan, discuss, and complete projects, such as the BAPORA project, in small groups, which increases their confidence, inspiration, and scientific cognition. In addition, the STEAM-PjBL approach places a greater focus on students' needs, which improves their decision-making ability and emphasizes application over theory (Demirel & Caymaz, 2015). It has also been previously stated that technology, physical space, and group projects can improve scientific literacy skills (S.-Y. Chen & Liu, 2018; Dragoș & Mih, 2015; Kadaritna et al., 2020; Turiman et al., 2012).

The STEAM-PjBL approach has been shown to be more effective in promoting satisfactory scientific literacy compared to the traditional approach, according to statistical analysis. This was because it promoted students to critically evaluate their test results, form opinions based on data, present arguments, and create projects while receiving instruction. The observation indicated that students had a solid grasp of the scientific principles behind the subject matter, and this allowed them to apply their knowledge and engage in scientific inquiry. Moreover, the STEAM-PjBL approach assisted students to connect their classroom learning to real-world situations (Azura et al., 2021; Owens & Hite, 2022).

The BAPORA project produced can provide an easier alternative for students when fuel prices are high through the application of the STEAM-PjBL which involved (a) the scientific study of energy and design, (b) the technical study of finding references and documenting STEAM project activities, (c) combining techniques and patterns, (d) artistic study of aircraft design activities and 3D projects, and (e) mathematical analysis of aircraft angles and plane shapes. These are the five aspects of science provided by the model to equip students in solving global issues. However, high-quality teachers with the ability to develop creative learning activities are required and this is the reason the connections among educational communities are important to bring the students closer to the real world through their surroundings. It was discovered that both STEAM/STEM and PjBL can increase scientific literacy. Meanwhile, this study only applied the STEAM-PjBL to assist students in designing projects based on scientific theories and concepts.

Conclusion

In conclusion, the implementation of the STEAM-PjBL approach in this study effectively addressed the gap caused by students with insufficient scientific literacy skills. The approach involved presenting real-world issues, seeking out information on potential solutions, designing and working on projects, collecting and analyzing data, and drawing conclusions, all of which were used to accelerate the development of students' scientific literacy skills. The findings of the study revealed that the STEAM-PjBL approach led to a significant improvement in students' scientific literacy skills in the experimental group ($t(24) = -15.23$, $p = 0.000$), as evidenced by an increase in the mean score across all subscales of scientific literacy ($p < 0.05$). Moreover, the experimental group demonstrated a greater improvement in scientific literacy skills compared to the conventional group, indicating that the STEAM-PjBL approach can serve as a viable alternative for teachers looking to increase scientific literacy and promote teacher innovation. However, future studies should expand and modify these findings to meet the needs of students with varying cognitive abilities and different course topics.

Recommendations

It is recommended that future studies use a larger sample size and extend the duration of the study to draw more meaningful comparisons between this approach and other non-traditional methodologies. Moreover, there is a need to integrate STEAM-PjBL with other more varied projects to determine students' scientific literacy skills to also improve with these projects. It was discovered that STEAM-PjBL improved scientific literacy and enabled students to analyze, synthesize, solve problems, and form conclusions. This process is an indicator of critical thinking, therefore, it is recommended that future study investigate how students acquire critical thinking skills through this learning.

Limitations

This study was limited to a single school with 48 students which were separated into control and experimental groups. However, the findings served as a precursor to a more comprehensive examination of students' scientific finalizations. It is also important to note that this study was confined to the fourth grade of primary school because it was designed to solve the difficulty in creating projects at the level.

Authorship Contribution Statement

Suryanti: Generating ideas and conceptualization, developing the research design, translating, and managing the entire research process. Nursalim: Field research including data collection. Yuliana: Writing the literature reviews, organizing the discussion and conclusion, and supervising the research. Choirunnisa: Data analysis, data presentation, results composition, and final editing.

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