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Project-based learning in improving scientific literacy: Systematic literature review

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Abstract: Scientific literacy is a necessary competency for students in the 21st century. The low level of scientific literacy among students in Indonesia can be attributed to a number of factors, including the learning model used. Several studies indicate that project-based learning can enhance students' scientific literacy. This study aims to present the findings of a literature review on project-based learning for increasing scientific literacy. The method employed was a systematic literature review. This study collected data from 2012 to 2022 based on a prism-shaped data extraction procedure diagram with specific criteria. According to the findings of this study, the project-based learning model can enhance scientific literacy in multiple fields of science, including physics, chemistry, biology, science, epidemiology, and environmental projects. Project-based learning is consistent with interdisciplinary learning because it naturally incorporates a variety of academic skills, such as reading, writing, and calculation, which can directly contribute to the development of conceptual understanding through the incorporation of other disciplines. Thus, the use of PjBL can improve students' scientific literacy.
Keywords: PjBL, Scientific Literacy, Literature Review

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INTRODUCTION

Students must be able to think critically, effectively collaborate and communicate their ideas, and solve problems creatively to solve everyday problems. Students can acquire these abilities if they possess scientific literacy. Scientific literacy encompasses both science and technology literacy. The variety of scientific literacy definitions results from its vast scope and long history (Roberts, 2007; Shofiyah et al., 2019; Webster et al., 2022). A person has scientific literacy if they can scientifically explain phenomena, comprehend scientific discoveries, and interpret scientific evidence (Organization for Economic Co-operation and Development, 2013).

Scientific literacy is one of the educational issues requiring immediate consideration In Indonesia. The results of an evaluation conducted by the Organization for Economic Cooperation and Development (OECD) as part of the Programme for International Student Assessment (PISA) in 2019 indicate that the scientific literacy of students in Indonesia remains inadequate and falls into the low category (Oliver et al., 2021; She et al., 2018; Sholikah & Pertiwi, 2021). The low levels of scientific literacy among Indonesian students can be attributed to a number of factors, including the learning model used by teachers and the instructional materials utilized

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by students (Rusilowati et al., 2019). Consideration must be given to the learning model when carrying out the learning process. Multiple studies have demonstrated that the implementation of appropriate learning models can enhance students' scientific literacy.

The project-based learning model organizes students to build their knowledge independently through investigation and discussion in order to achieve predetermined goals (Jagantara et al., 2014; Tseng et al., 2013). Students' attitudes toward scientific literacy can be improved through project-based learning (Juntunen & Aksela, 2013). It is necessary to conduct a literature review on the effectiveness of project-based learning in enhancing scientific literacy. The goal is to prove the existence of scientific literacy improvement through a project-based learning model.

The researchers gathered articles based on the Scopus index in conducting this study. Scopus is one of the citation and scientific literature databases owned by Elsevier, the world's foremost publisher (Burnham, 2006; Harzing & Alakangas, 2016). In addition to providing scientific papers, Scopus also provides patent information on a variety of global studies. Scopus also offers a service to determine whether or not a journal has a significant impact. Scopus-indexed journals are reputable international publications (Boyle & Sherman, 2006; Gavel & Iselid, 2008; Mongeon & Paul-Hus, 2016). The Scopus index was selected due to the fact that its credibility is no longer in question. This study aims to determine the influence of project-based learning on the development of scientific literacy.

METHODS

This article employed a systematic literature review method. Figure 1 depicts the stages involved in conducting a systematic literature review in the field of education (Kerres & Bedenlier, 2020).

Figure 1. Diagram of Systematic Literature Review Stages

Determining the Research Question

The question is determined by the needs of 21st-century skills, which include basic literacy skills, competencies, and character qualities to confront the life challenges that are constantly changing. To equip Indonesian students with 21st-century skills, such as scientific literacy, the government's primary concentration in education is on literacy. In this instance, scientific literacy can be enhanced via learning models like project-based learning (PjBL). Consequently, this study provides a systematic literature review on project-based learning to enhance scientific literacy. This study's research questions are: (1) How does project-based learning improve students' scientific literacy? (2) What are the objectives and results of research on project-based learning models in improving scientific literacy over the past ten years? (3) What are the limitations of research on project-based learning models for improving scientific literacy?

Devising Research Plan

Some planning was conducted in order to answer the research questions before searching for relevant article data. This is conducted to ensure that the analyzed articles are valid, credible, and trustworthy research. In this instance, the author selected articles indexed by Scopus.

Searching for the Literature

The search was conducted on the Scopus website on November 24, 2022, using a search string. There is a need for search strings to obtain more specific documents and avoid excessive filtering. The search terms in Scopus are TITLE-ABS-KEY (("Project Based Learning" OR "PjBL") AND ("Scientific Literacy")).

The obtained results are depicted in Figure 2, which shows the distribution of the number of articles by string from 2012 to 2022. In this instance, 22 articles were discovered. Research on scientific literacy in project-based learning attained its peak of six articles in 2021, compared to zero articles in 2015 and 2017, as shown in Figure 2.

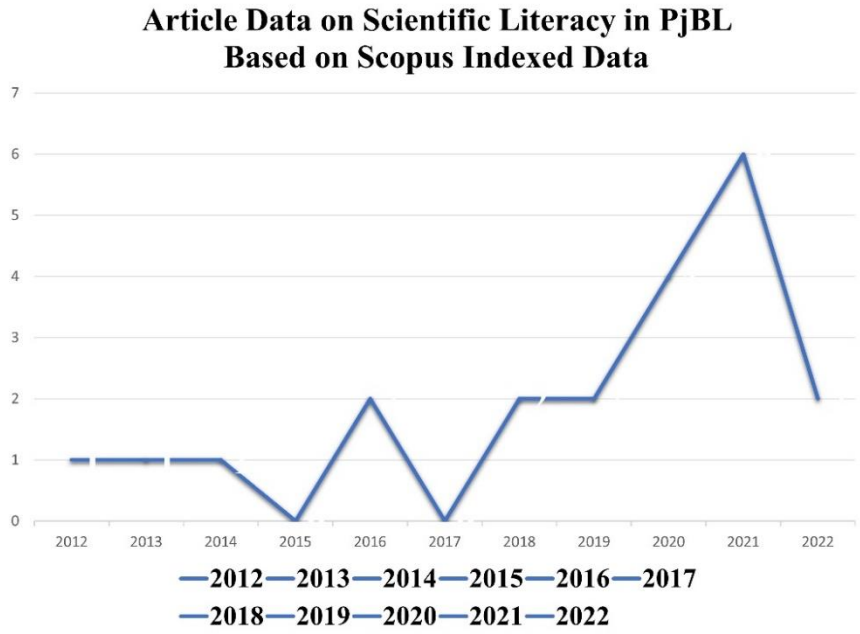

Figure 2. Scopus-indexed research article on scientific literacy in project-based learning

Applying Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were established according to Table 1 to screen the articles for relevance to the research objectives. The PRISMA 2020 method is utilized to extract data from inclusion and exclusion criteria. Figure 3 demonstrates the results of data extraction.

Table 1. The inclusion and exclusion criteria

Inclusion criteria (Acceptance)
1. The article is appropriate for the research topic a. Project-based learning (PjBL) b. Scientific Literacy 2. Full text (not only abstract or conclusion) 3. Open access
Exclusion criteria (rejection)
1. Out of topic: Naj'íyah et al. (2021) with the title "Learning strategies design to accommodate learning styles, initial knowledge and reduce the differences of scientific reasoning and argumentation performance." Rejected due to the lack of explanation of scientific literacy. 2. *not full-text* none 3. Close access

a. Heilmayr (2022) with the title: "A course unit and presentation assignment to teach students about open science and replicability in psychology."
b. Koes and Putri (2021) with the title: "The effect of project-based learning in STEM on students' scientific reasoning"
c. Mustikasari et al. (2018) with the title: "Design action in primary school students class V for high and medium group related food themes."
d. Parno et al. (2020) with the title: "Designing and implementing STEM-based teaching materials of static fluid to increase scientific literacy skills."
e. Rusilowati et al. (2019) with the title: "Media-savvy scientific literacy Developing critical evaluation skills by investigating scientific claims."
f. Afriana et al. (2016) with the title: "Project-based learning integrated to stem to enhance elementary school students' scientific literacy."
g. Suryandari et al. (2018) with the title: "Project-based Science Learning and pre-service teachers' Science Literacy Skill and Creative Thinking."
h. Mustikasari et al. (2019) with the title: "The implementation of PjBL-STEM model to improve eight graders' scientific literacy."
i. McRae (2014) with the title: Media Space

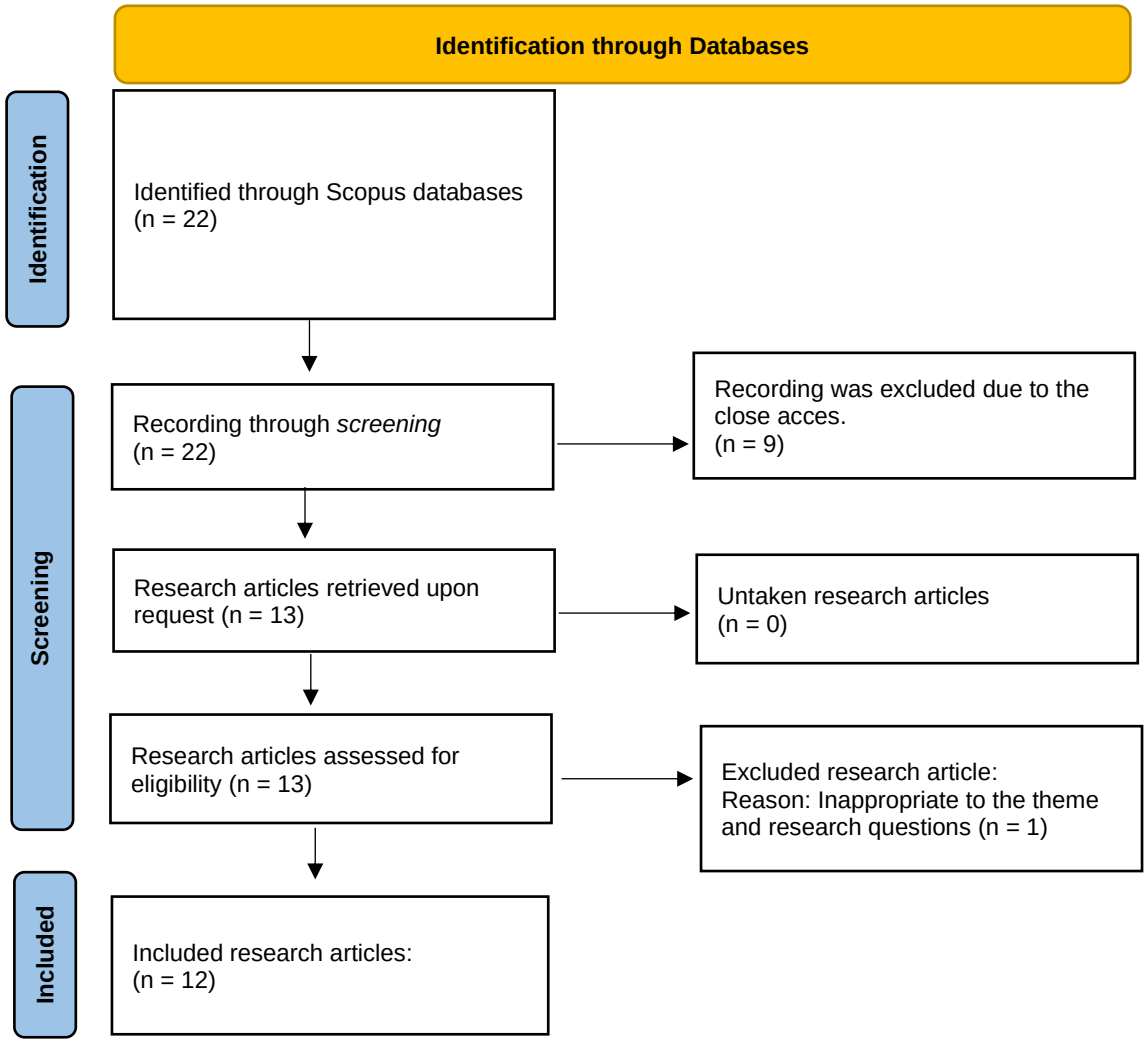

Figure 3. Diagram of Prisma Procedure Data Extraction

Ten articles were rejected based on the inclusion and exclusion criteria of the 22 articles found. Therefore, twelve articles were analyzed in this study.

Applying Quality Assessment

The synthesized articles must be ensured that they are of high quality. The quality of the article assessment can be determined by whether or not the article contains a pertinent research problem. The criteria for article quality are listed in Table 2.

Table 2. The criteria for article quality

The criteria of the quality
1. The article contains clear objectives regarding project-based learning in improving scientific literacy.
2. The article contains significant findings regarding the influence of project-based learning in improving scientific literacy.
3. The article contains supporting data explaining how project-based learning improves scientific literacy.

Synthesis

Synthesis is carried out by analyzing the included articles and answering the questions determined at the outset through a review of the literature and supporting research.

RESULTS AND DISCUSSION

In this section, the answers to the research questions are provided through analysis of the selected articles. It is structured according to the questions posed and presented as systematic literature review (SLR) findings.

How does the Project-Based Learning Model Improve Scientific Literacy?

The findings of the articles that met the inclusion criteria showed that there are a variety of researcher perspectives on project-based learning (PjBL) as it relates to enhancing scientific literacy. Multiple factors contribute to the diversity of the perspectives, including distinctions in research objectives and indicators of scientific literacy. Figure 4 presents the data of the research targets employed by the researchers.

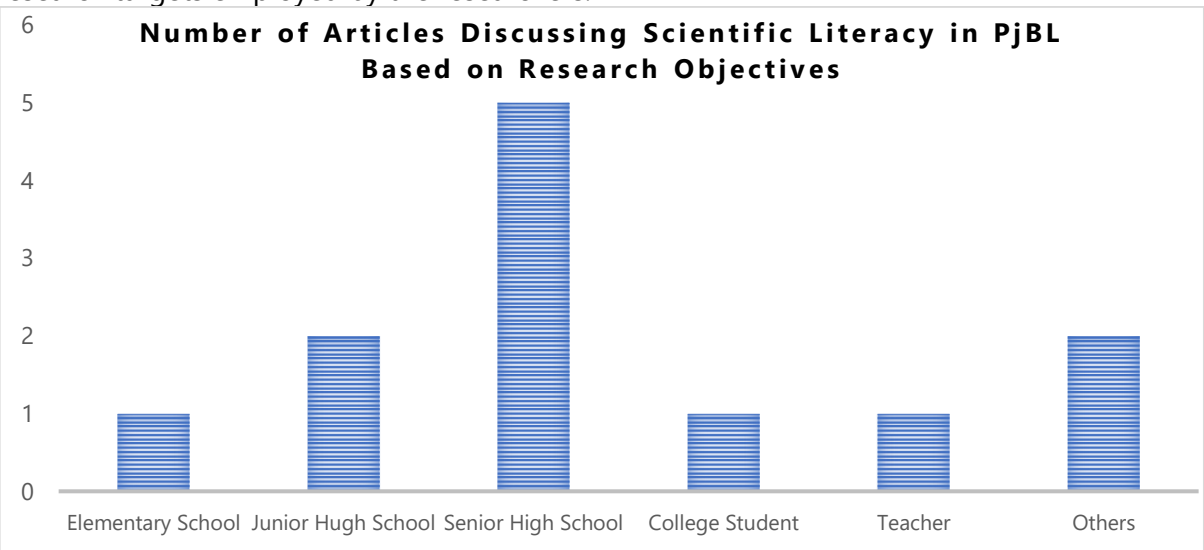

Figure 4. The number of articles on scientific literacy in PjBL based on research targets

The difference in education level in applying PjBL lies in the level of cognitive aptitude (Flemming, 2000; Hasni et al., 2016; Kokotsaki et al., 2016). The higher the thinking ability, the more complicated the project. For instance, in the research conducted by Adriyawati et al. (2020), the PjBL model was used to assess scientific literacy among elementary school students

studying energy materials. The project was the creation of miniatures relating to the concept of renewable energy. Indicators of scientific literacy used include scientific ideas, science characteristics, science in context, higher-order thinking skills, and attitudes. Meanwhile, PjBL is different at the high school level, as in the research of Ahmada et al. (2021) that seeks to analyze the impact of PjBL-STEM on the scientific literacy of high school students in the biology subject chapter of the circulatory, digestive, and respiratory systems. In his research, the students were required to solve problems that resulted in the creation of a product. The resulting products range from solution concepts to devices that can be perceived through the five senses. In the process, nine scientific literacy indicators are assessed, namely: (1) identify valid scientific arguments, (2) evaluate the validity of sources, (3) evaluate the use and misuse of scientific information, (4) comprehend the elements of research design and how they affect scientific findings/conclusions, (5) create graphical representations of data, (6) read and interpret graphical representations of data, (7) solve problems using quantitative skills including probability and statistics, (8) comprehend and interpret basic statistics, and (9) drawing conclusion and confirming prediction based on the quantitative data. These differences in the level of cognitive aptitude affect the indicators of scientific literacy.

The following distribution of learning materials or objects in the application of project-based learning to enhance scientific literacy is observed:

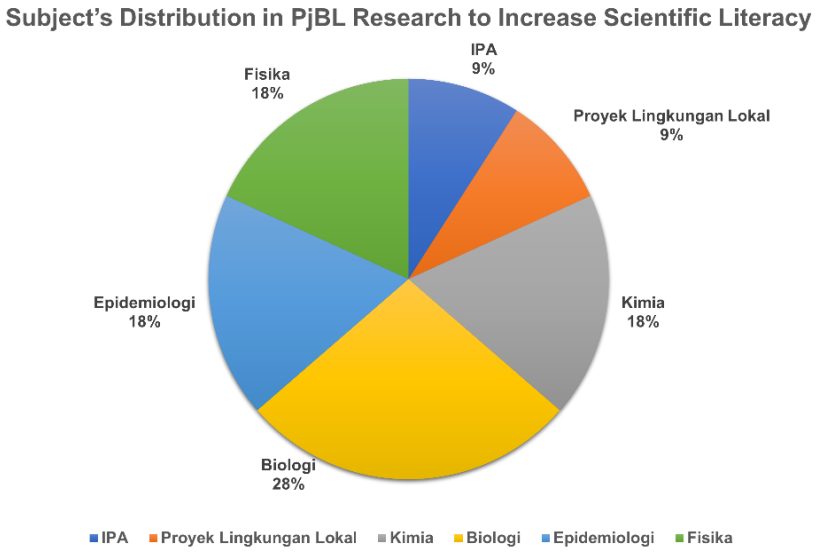

Figure 5. Distribution of learning materials in the PjBL research in improving scientific literacy

Figure 5 demonstrates that the project-based learning model can increase scientific literacy in more than one discipline of science, including physics, chemistry, biology, science, epidemiology, and environmental projects. Project-based learning is consis-tent with interdisciplinary learning because it inherently involves a variety of academic skills, such as reading, writing, and counting, which can directly contribute to the deve-lopment of conceptual understanding through the incorporation of other disciplines. Hence, the implementation of PjBL can enhance students' scientific literacy.

What are the Objectives and Results of Research on Project-Based Learning Models in Improving Scientific Literacy Over the Past Ten Years?

The objectives and results of research on project-based learning models in improv-ing scientific literacy in the last ten years are listed in Table 3.

Table 3. The objectives and results of research on PjBL in improving scientific literacy

No.	Research	Objectives	Result
1.	Adriyawati et al. (2020)	Identifying the relationship between STEAM-PjBL and scientific literacy	The average level of scientific literacy is high. STEAM-PjBL can help students connect knowledge with everyday life, increase curiosity, improve problem-solving skills, increase confidence to ask questions, and gather information from various sources. PjBL makes learning becomes more meaningful.
2.	Ahmada et al. (2021)	Analyzing the effect of PjBL-STEM on the scientific literacy of students	There was an increase in scientific literacy in each indicator, namely identifying scientific arguments, evaluating valid sources, understanding conclusions from scientific sources, constructing graphical representations, solving problems using quantitative data, understanding and interpreting statistical data, and drawing conclusions from quantitative data processing.
3.	Alghamdi et al. (2022)	Training teachers to improve students' scientific literacy through workshops with several themes, one of which is project-based learning	There is a strong correlation between the cognitive level of teachers in appliance and their application of project-based learning and mind maps to facilitate students' conceptual change regarding medical terminology and COVID-19 epidemiology.
4.	Sholahuddin et al. (2021)	Analyzing the effect of PjBL on scientific literacy through the ethnoscience study of traditional Banjarese cuisine	PjBL can help students move from the low category to the high category in terms of knowledge and scientific literacy.
5.	Khotimah et al. (2021)	(1) Describing STEM-based learning models in Indonesia, (2) describing STEM-based education levels in Indonesia, and (3) examining the impact of STEM on Indonesian students	(1) STEM learning models used in Indonesia include PjBL, PBL, 6E, and inquiry. PjBL holds the highest proportion, which is 40%. In this instance, STEM-based PjBL influences scientific literacy, creative thinking, critical thinking, and 21st-century skills; (2) STEM is prevalent in high school; (3) STEM positively impacts scientific literacy, creative and critical thinking, problem-solving ability, and attitude.
6.	Parno et al. (2020)	Investigating the impact of PjBL STEM on scientific literacy	The level of scientific literacy in the PjBL STEM class was rated as high.
7.	Rusmansyah et al. (2021)	Developing electronic modules using STEM-PjBL	The e-module has satisfied the valid, applicable, and efficient criteria. Effectiveness demonstrates the influence of e-modules on scientific literacy by producing a positive N-Gain and a high category.
8.	Webster et al. (2022)	Describing university students' experiences with project-based learning (PjBL)	PjBL on introductory biology material can provide students with beneficial experiences, including the enhancement of scientific literacy skills.

No.	Research	Objectives	Result
9.	Wilson et al. (2018)	Describe the project-based learning of the Epi challenge project and the short-term change outcomes of scientific literacy and science-related motivation and beliefs.	There was an increase in scientific literacy scores. In this case, the researchers employed the SLA-MB instrument (Scientific Literacy Assessment in the Motivation and Belief category) with three criteria: Value of Science, Scientific Self-efficacy, and Personal Scientific Epistemology. The categories with the greatest increase in scientific literacy scores are Scientific Self-Efficacy and Personal Scientific Epistemology.
10.	Basche et al. (2016)	Evaluating the effectiveness of PjBL used with middle school students to teach environmental science topics, using a unique curriculum developed in the classroom through a partnership between GK-12 teachers	PjBL positively impacts students' scientific literacy in terms of attitude, engagement, and confidence.
11.	Rusilowati et al. (2019)	Analyzing the factors that influence the scientific literacy of students in Indonesia, describing the scientific literacy students profile based on scientific literacy-based science texts, learning models, worksheets, and assessment tools	Textbooks, learning models, worksheets, and assessment tools based on scientific literacy can help students enhance their scientific literacy. In this situation, project-based learning and problem-based learning are the learning models that can enhance students' scientific literacy.
12.	Kostelníková & Ožvoldová (2013)	Seeking the impact of project-based learning reinforced by remote experiments on students' development in scientific literacy and the durability of the knowledge and skills they acquire	The project was designed and implemented in the learning process in four Slovak junior high schools. Pre-research findings indicated that remote energy experiments in nature, technology, and society were successful. Students in the test group attained higher levels of scientific literacy related to knowledge and data processing skills. These students also demonstrated higher levels of sustainability of knowledge and abilities in the second test. There was a favorable shift in the way the students perceived physics, and they showed good attitudes toward remote experiments and project-based learning with RE.

The article review results demonstrate that the objective of PjBL research to improve scientific literacy gave positive results. In addition, five articles integrate PjBL with the STEM (science, technology, engineering, and mathematics) learning approach. (Rizki et al., 2022; Winarni et al., 2022) report that integrating project-based learning and STEM can positively affect a variety of essential 21st-century skills, such as problem-solving, creativity, literacy, and collaboration. The results presented in the article PjBL can enhance scientific literacy in a variety of disciplines, including science, social, and mathematics.

What are Research Limitations on Project-Based Learning Models for Improving Scientific Literacy?

Table 4 summarizes the limitations of the project-based learning research for improving scientific literacy.

Table 4. The limitations of the PjBL research for improving scientific literacy

No.	Research	Targets	Limitation
1.	Adriyawati et al. (2020)	Elementary students	Time management, students' engagement, and project ideas development based on instructional materials
2.	Ahmada et al. (2021)	Senior high school students	Not mentioned
3.	Alghamdi et al. (2022)	Teachers	The urgency of attending seminars for teachers to enhance curricula and initiative learning activities
4.	Sholahuddin et al. (2021)	Senior high school students	The integration of ethnoscience projects with chemical topics, especially when traditional regional cuisines are included, consumes a lot of time.
5.	Khotimah et al. (2021)	Research literature at elementary schools, junior and senior high schools	Lack of sufficient STEM research in higher education
6.	Parno et al. (2020)	Senior high school students	The necessity of project restrictions. As a result, the implementation of fluid projects utilizing readily available equipment and discussed topics do not expand and bias
7.	Rusmansyah et al. (2021)	Senior high school students	Not mentioned
8.	Webster et al. (2022)	University students	Not mentioned
9.	Wilson et al. (2018)	Junior high school students	The ignorance of the additional variables such as parental participation, student absences, past STEM experience, and prior levels of scientific performance
10.	Basche et al. (2016)	Junior high school students	Not mentioned
11.	Rusilowati et al. (2019)	Junior high schools in Central Java, South Sulawesi, and North Sumatera	Not mentioned
12.	Kostelníková & Ožvoldová (2013)	Junior high school students	Not mentioned

The findings of the article review indicate that the limitations of PjBL research in improving scientific literacy are primarily of a technical nature. It takes considerable time to implement PjBL, which is a limitation. This condition is caused by the fact that teachers are required to cover a great deal of material quickly. One solution is for the Indonesian government to implement a Merdeka curriculum in which only essential material is included, and development is left to the teacher's discretion (Jenita et al., 2022; Krishnapatria, 2021). PjBL and problem-

based learning are also included among the suggested learning models. In addition, the reviewed articles are limited by the absence of PjBL research within the scope or at the level of higher education.

CONCLUSION

Project-based learning can improve scientific literacy, for it requires the application of multiple academic skills, such as reading, writing, and counting, which can directly contribute to the development of conceptual understanding through the incorporation of other disciplines. Therefore, the implementation of PjBL can enhance students' scientific literacy. The findings of this systematic literature review are extremely diverse. The project-based learning can increase scientific literacy based on several indicators. However, scientific literacy is not a rigid criterion, as the scientific literacy required by the periods changes as time progresses. The Organization for Economic Co-operation and Development (2013) report on scientific literacy competencies is depicted in Table 5.

Table 5. Scientific Literacy Competencies from 2000 until 2015

Scientific Literacy Competencies in 2000	Scientific Literacy Competencies in 2006	Scientific Literacy Competencies in 2015
Using scientific knowledge	Identifying scientific issues	Explaining phenomena scientifically
Identifying questions	Explaining phenomena scientifically	Comprehending scientific discoveries
Drawing a conclusion based on evidence	Using scientific evidence	Interpreting scientific evidence

This systematic literature review demonstrates that project-based learning can enhance students' scientific literacy. In this instance, the researchers discovered a disparity between scientific literacy indicators from different studies. Some studies have determined scientific literacy indicators based on the Scientific Literacy Assessment, while others have not or do not even mention the scientific literacy indicators measured. The indicators of scientific literacy must be included as a solid foundation if they are to equip students with 21st-century skills.

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