JPPIPA 11(1) (2025)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Literature Review: The Impact of Project Based Learning on Scientific Literacy in Secondary Education

Miftahul Hasanatun Alfiah[1*], Bramastia[1], Sukarmin[1]

[1] Master of Science Education Program, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia.

Received: July 23, 2024
Revised: November 21, 2024
Accepted: January 25, 2025
Published: January 31, 2025

Corresponding Author:
Miftahul Hasanatun Alfiah
miftahulhasanatun@student.uns.ac.id

DOI: 10.29303/jppipa.v11i1.8616

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Abstract: Technological advancements have significantly impacted the environment, highlighting the need to improve scientific literacy to address these effects. However, PISA data indicates that Indonesian students' scientific literacy remains low. This study aims to analyze the effectiveness of Project-Based Learning (PjBL) in enhancing scientific literacy among secondary school students through a literature review method. PjBL fosters active engagement, collaboration, and critical thinking by involving students in meaningful projects. The findings demonstrate that PjBL improves scientific literacy and creativity, though its implementation faces challenges such as limited resources, time constraints, and insufficient teacher training. The study concludes that PjBL is a promising approach to improving scientific literacy in Indonesia, provided adequate teacher training and resources are available to support its implementation.

Keywords: Educational challenges**;** PjBL; Science literacy; Secondary education

Introduction

Technological advancements have elevated human civilization, allowing for the easy and rapid fulfillment of needs through various innovations. However, their negative impact on the environment is significant. Uncontrolled use of technology has led to severe pollution, exemplified by incidents such as the methyl isocyanate gas leak in Bhopal in 1984 and the nuclear reactor damage due to an earthquake in Fukushima in 2011. Additionally, natural ecosystems have been disrupted by excessive human activities, including the use of pesticides and chemicals that harm the natural balance. Therefore, despite the numerous benefits technology offers, wise and responsible management is crucial to mitigate its adverse effects on the environment and ensure ecosystem sustainability (Sonhadji, 2018). Technological progress is inevitable as it is an integral part of human civilization's development. However, certain measures need to be taken to balance this advancement. This is to ensure that technological developments not only provide maximum benefits but also minimize potential negative impacts. One effective approach is to enhance students' scientific literacy.

Scientific literacy encompasses not only a deep understanding of scientific concepts but also the ability to apply this knowledge in everyday life, make evidence-based decisions, and participate in science-related discussions. These skills are essential for equipping students to face challenges and make informed decisions in an increasingly complex world. With this knowledge, students can use technology more wisely and critically assess new innovations. Furthermore, strong scientific literacy can encourage students to actively engage in research and the development of green technologies, such as renewable energy, which can be used as safer and more efficient alternative energy solutions. Therefore, it can be concluded that scientific literacy not only prepares students for technological advancements but also instills awareness of their responsibility to maintain environmental sustainability (Kemdikbud, 2017).

How to Cite:
Alfiah, M. H., Bramastia, & Sukarmin. (2025). Literature Review: The Impact of Project Based Learning on Scientific Literacy in Secondary Education. *Jurnal Penelitian Pendidikan IPA*, *11*(1), 1–9. https://doi.org/10.29303/jppipa.v11i1.8616

However, data shows that scientific literacy among Indonesian students is still at a concerning level, as evidenced by PISA scores. The Programme for International Student Assessment (PISA) is a tool used to evaluate secondary education performance in various countries, focusing on reading, mathematics, and science skills. Organized by the Organization for Economic Cooperation and Development (OECD), PISA tests 15-year-old students, who are typically in the 9th grade of junior high school or the beginning of high school, and is conducted every three years with an emphasis on one subject. In 2018, PISA results showed a decline in Indonesia's ranking compared to 2015. Over the past four PISA cycles, from 2006 to 2015, Indonesian students' science literacy scores consistently ranged between 382 and 403. In 2018, Indonesia's science literacy score dropped again to 396 (Yusmar & Fadilah, 2023). According to this data, Indonesian students rank poorly in scientific literacy compared to other countries. In 2022, the PISA scores (PISA, 2023) placed Indonesian students at 69th out of 81 countries, with a score of 398. This indicates that Indonesian students still struggle with mastering science material and have poor analytical skills. The trend in Indonesian students' scientific literacy also shows fluctuations in competency achievement and Indonesia's ranking compared to other countries. To improve literacy, improvements in teaching practices, classroom climate, and reading metacognition strategies are needed, as well as increasing public awareness of the importance of literacy (Bramastia et al., 2023).

This gap in scientific literacy can negatively impact the younger generation's ability to participate in a knowledge- and technology-based society. Therefore, efforts are needed to enhance scientific literacy among students. One approach believed to improve scientific literacy is the Project-Based Learning (PjBL) method. PjBL is a learning method that places students at the center of learning through complex projects that reflect real-world challenges. Through PjBL, students are expected to develop critical thinking, collaboration, and problem-solving skills, all of which are essential components of scientific literacy. This method provides students with the opportunity to actively engage in the learning process, explore scientific concepts in depth, and apply their knowledge in real-world situations. Thus, PjBL not only enhances students' understanding of scientific concepts but also their ability to apply this knowledge in real-life contexts (Werdiningsih et al., 2021).

This study offers a novel contribution by conducting a comprehensive literature review to synthesize existing research on the effectiveness of PjBL in enhancing scientific literacy in secondary education. Unlike previous studies that focus on isolated aspects of PjBL, this research aims to provide a holistic understanding of how PjBL can be optimized to address Indonesia's unique educational challenges. Additionally, the study identifies critical factors influencing PjBL implementation, such as teacher training, project design, and resource availability, and proposes actionable strategies to overcome these barriers.

Additionally, the implementation of PjBL faces various challenges. One major challenge is the need for a paradigm shift in how teachers teach and how students learn. Teachers must be able to design and facilitate projects that are not only engaging but also meaningful and relevant to the curriculum (Fatimah et al., 2023). Students must also be able to work independently and collaboratively and be highly motivated to complete the projects. These challenges must be addressed to ensure the success of PjBL in enhancing scientific literacy. Through this literature review, it is hoped that best practices in implementing PjBL to improve scientific literacy can be identified. By understanding the key factors contributing to the success of PjBL, educators and policymakers can develop more effective strategies to enhance scientific literacy in secondary schools. This review will also provide insights into how PjBL can be integrated into existing curricula and offer recommendations for further research in this field.

The significance of this research lies in its potential to guide educators and policymakers in developing evidence-based strategies to improve scientific literacy, thereby preparing students to navigate technological advancements responsibly. By aligning educational practices with the demands of the 21st century, this study contributes to building a scientifically literate society capable of balancing innovation with sustainability.

In conclusion, scientific literacy is an essential skill that every student must possess to face future challenges. PjBL offers a promising approach to enhancing scientific literacy, but further research is needed to understand how this model can be effectively implemented in various educational contexts. Through this study, it is hoped that ways to optimize the implementation of PjBL can be found, thereby providing maximum benefits for improving scientific literacy among secondary school students.

Method

This research adopts a literature review approach to evaluate the relationship between Project Based Learning (PjBL) methods and scientific literacy in secondary education. This research approach was chosen because it allows researchers to gather, analyze, and synthesize various previous studies, thereby

obtaining a comprehensive overview of the researched topic.

Research Design

The research design employed in this study is a systematic literature review, aiming to identify, assess, and interpret all relevant research related to the impact of PjBL on scientific literacy. This review will follow the systematic steps proposed by Khan (Khan, 2020) to ensure that the data collection and analysis processes are conducted consistently and transparently. The following are the steps used.

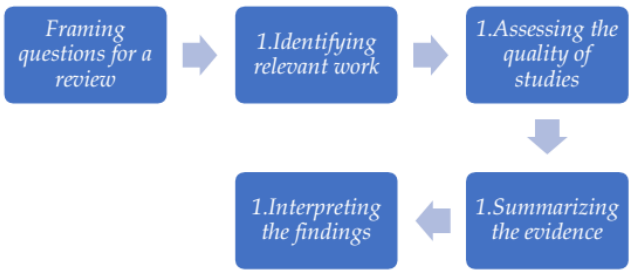

Figure 1. Research flow

Framing questions for a review

Formulating well-structured questions is a crucial step in conducting a literature review. The questions for the literature review should be specific, clear, and relevant to the research objectives. This study formulates several key research questions to explore the relationship between Project-Based Learning (PjBL) and scientific literacy among secondary school students. The primary focus is on understanding the impact of implementing PjBL on students' scientific literacy and whether it significantly enhances their understanding compared to traditional teaching methods. Additionally, the study seeks to identify the core components within PjBL, such as collaboration, problem-solving, and real-world application, that effectively contribute to improving scientific literacy.

Another critical aspect of the inquiry involves examining the factors that influence the success of PjBL in fostering scientific literacy. These factors include the quality of project design, the level of teacher support, and the characteristics of students participating in the learning process. The study also explores students' responses to learning science through PjBL, focusing on their motivation, engagement, and overall learning satisfaction.

Lastly, the challenges faced by teachers in implementing PjBL are addressed, particularly in areas such as training, resource availability, and classroom management. By investigating these dimensions, the study aims to provide a comprehensive understanding of PjBL's role in enhancing scientific literacy and offer valuable insights for educators and policymakers.By answering these questions, this literature review is expected to provide a comprehensive overview of the impact of Project-Based Learning on scientific literacy in secondary education and provide insights and recommendations for the development of future educational policies and practices.

Identifying relevant work

In this stage, the researcher identifies relevant sources of information related to the topic or field of the literature review. The researcher uses keywords related to the topic, namely Project Based Learning and scientific literacy of students. The information sources used are only journal articles and conference papers obtained from Scopus, Google Scholar, and ResearchGate. This study applies clear inclusion and exclusion criteria to ensure the relevance and quality of the selected literature. The inclusion criteria specify that only research articles published between 2020 and 2024 are considered. These articles must specifically discuss the impact of Project-Based Learning on scientific literacy and be published in academic journals. Furthermore, the studies must focus on secondary education, including junior high schools and senior high schools.

To maintain the scope and focus of the review, exclusion criteria are also applied. Studies published before 2020 are excluded, as are those that do not specifically address the relationship between Project-Based Learning and scientific literacy. Additionally, research presented in forms other than journal articles, such as books or reports, is excluded. Studies that are not available in full text or those conducted outside the secondary education level are also omitted.

Assessing the quality of studies

After identifying relevant research articles, the next step is to assess the quality of the selected studies. Evaluating the quality of studies is important to ensure that the conclusions drawn are based on strong and reliable evidence. Rigorous quality assessment also helps identify weaknesses in the existing literature and provide recommendations for future research.

Summarizing the evidence

Summarizing evidence in a systematic review is an important process to convey relevant, accurate, and easily understandable information. Summarizing evidence in a systematic review involves synthesizing and interpreting the results of the studies included in the review. In this study, the information sources used are only journal articles obtained from Mendeley, Google Scholar, and ResearchGate. At this stage, the summary includes various aspects of the studies on the impact of

Project Based Learning on scientific literacy in secondary education.

Interpreting the findings

Interpreting findings in a systematic review involves analyzing and deciphering the results of the studies included in the review. The aim of interpreting findings is to provide a deep understanding of the implications of the existing evidence and provide relevant answers to the research questions.

Data Collection Procedure

Literature search will be conducted through academic databases such as Google Scholar, Mendeley, and ResearchGate. Keywords used include "Project Based Learning and scientific literacy." Articles found will be selected based on their titles and abstracts. Articles that meet the inclusion criteria will be downloaded for evaluation. The selected articles will be assessed for quality to ensure that the conclusions drawn are based on strong and reliable evidence.

The collected data will be analyzed using a narrative synthesis approach. This involves a detailed description of each study, including objectives, methods, results, and conclusions. Findings from various studies will be compared and contrasted to identify patterns, differences, and factors influencing the outcomes. Findings from various studies will be categorized into main themes that emerge, such as the effectiveness of PjBL in improving scientific literacy, challenges in implementing PjBL, and factors supporting the success of PjBL.

The research findings will be systematically reported, including main findings, data interpretation, and implications for educational practice and further research. This reporting will follow the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Khan, 2020) to ensure completeness and transparency. By using this research method, it is hoped that this study can make a significant contribution to understanding the relationship between Project Based Learning and scientific literacy and provide useful recommendations for educators and policymakers in developing effective teaching strategies research design and method should be clearly defined.

Result and Discussion

In this research, the information sources used are only journal articles obtained from Mendeley, Google Scholar, and ResearchGate. In Mendeley, using the keywords "Project Based Learning and Science Literacy" in the article titles and applying the criteria mentioned above, 202 documents were obtained. Meanwhile, on ResearchGate, 130 articles were obtained, and on Google Scholar, 59 articles were obtained. Duplicate studies were removed from all these articles. Afterward, the journal articles were further filtered to include only open-access articles, resulting in 43 fully accessible journals. From these journals, articles were selected that were most relevant to the research questions and met the inclusion criteria, resulting in the selection of 12 journal articles reviewed in this study.

Below is the PRISMA flowchart outlining the literature search process used in the review.

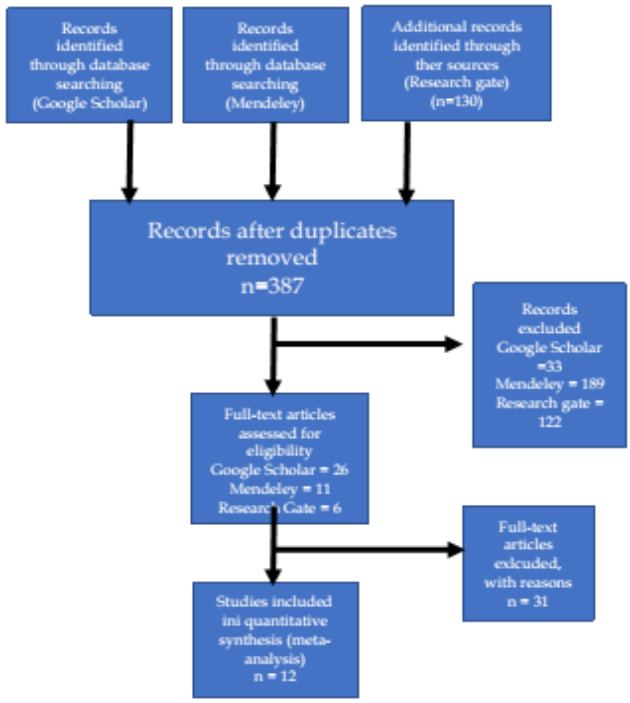

Figure 2. PRISMA flow scheme

Here is the table summarizing the results of various journal articles collected and selected for review:

Table 1. Reviewed Journal Articles

Title Study	Results	Source Reference
Effectiveness STEM Learning –Project-Based Learning in Improving Ability Scientific Literacy and Thinking Creative Students on Chemical Equilibrium Material	The application of STEM–project-based learning (STEM-PjBL) can develop students' creative thinking and science literacy in terms of knowledge.	(Zahirah & Sulistina, 2023)
The Influence of the Project Based Learning Model on Biological Science Literacy Class X	The Project-Based Learning (PjBL) model applied by teachers enhances students' learning outcomes by encouraging independent learning and	(Komalasari et al., 2024)

Title Study	Results	Source Reference
of SMAN 7 Mataram Acadenic Year 2023/2024	creativity. The project-making process and project presentation show an increase in students' science literacy.	
The Effect of Project Based Learning on Making Preserved Bioplastics to Ability Think Students ' Creative and Scientific Literacy	The application of the Project Based Learning (PjBL) model through the creation of bioplastic specimens improves students' creative thinking and science literacy in class X MAN 1 West Lombok. This systematic project facilitates students in understanding biodiversity material. Thus, the PjBL model is effective in developing students' creative thinking skills and science literacy.	(Handayani et al., 2023)
Project-Based and Flipped Learning in the Classroom: A Strategy for Enhancing Students' Scientific Literacy	The application of the project-based flipped classroom (PjBL-FC) learning model integrated with student environment learning sources can enhance students' scientific literacy compared to those only applying the PjBL model.	(Sholahuddin et al., 2022)
The Effect of The Project Based Learning Model on Students' Science Literacy Skills and Self Efficacy	The PjBL model has been proven to increase the average science literacy skills and self-efficacy of students.	(Anjli et al., 2023)
Project-Based Learning With Digital Storytelling to Improve Science Literacy of 10th Grade Students in MA AL Manshuriyah School	There is an influence of the PjBL model with digital storytelling on students' science literacy in ecosystem material.	(Munawar et al., 2023)
Effectiveness of project-based learning in improving science literacy and collaborative skills of Muhammadiyah middle school students	This research shows that the project-based learning (PjBL) model has a significant effect on students' science literacy and collaborative skills.	(Hindun et al., 2024)
The Implementation of Project Based Learning to Train the Ability of 21st Century Botanical Literacy in High School Students	The implementation of the PjBL model can increase plant taxonomy with a moderate category, except for the effective reasoning aspect, which is in the low category.	(Rizkamariana et al., 2019)
Project Based Learning on Science- Based Literacy Culture Local Nautical With Use of Wind Detection Tools	Project-Based Learning on Local Maritime Culture Science Literacy with wind detection can increase science literacy and enrich the science learning process.	(Kahiking, 2022)
The Influence of the Project Based Learning Model on Creativity Thinking and Scientific Literacy of SMAN I Gerung Students in 2018/2019	Project-Based Learning has the potential to improve creative thinking and science literacy.	(Raehanah et al., 2020)
The Effect of Project Based Learning (PjBL) Model on Students' Science Literacy in Social Studies Subjects	There is a significant influence of learning with the PjBL model on students' science literacy in Social Studies subjects with the theme of fire disaster mitigation in residential areas.	(Wardah et al., 2022)
Implementation of Project Based Learning Models to Improve Science Literacy of Junior High School Students	The implementation of project-based learning (PjBL) models enhances science literacy.	(Fauziah et al., 2023)

Discussion

Effectiveness of PjBL

Based on the analysis of various articles as shown in Table 1, it can be observed that the implementation of the Project-Based Learning (PjBL) model has been proven to enhance students' science literacy abilities among high school students. Through this model, students are not merely seated in classrooms receiving knowledge passively; instead, they actively engage in projects that require problem-solving, research, and data analysis. Consequently, students not only acquire an understanding of scientific concepts but also develop critical skills such as creative thinking, analytical thinking, and the ability to make scientifically informed decisions.

One study highlights how Project-Based Learning (PjBL) enhances science literacy through plant-based projects, such as designing plant growth experiments or investigating local ecosystems. These activities enable students to apply scientific concepts in real-world contexts, deepening their understanding, sparking interest, and motivating further learning. By engaging students in meaningful and challenging projects, PjBL not only builds scientific knowledge but also fosters skills and interests that support long-term academic and professional growth.

Components of PjBL Supporting Science Literacy

Project-Based Learning (PjBL) integrates several key components that significantly contribute to improving students' science literacy. First, collaboration is a crucial element in solving complex projects. In PjBL, students need to share ideas, solve problems together, and use their individual skills to achieve common goals. This not only develops teamwork skills but also reinforces understanding of project topics and enhances students' ability to make scientifically informed decisions.

Secondly, PjBL encourages students to inquire to help build a better understanding of the material. This allows students to have a strong knowledge base that can be applied in their projects. Discussions and interactions among students in the learning process also increase students' motivation to learn, which in turn contributes to higher achievements in science literacy.

Finally, the stages in the PjBL model, especially the project implementation stage, play a crucial role in enhancing science literacy. At this stage, students directly face problems relevant to their daily lives, allowing them to apply scientific concepts in real-world contexts. This process encourages students to think creatively and develop unique strategies to solve challenges, thereby strengthening their understanding of scientific concepts.

Student Response

Students respond positively to the use of Project-Based Learning (PjBL) in science education in high schools. From survey results in various studies, most students agree that activities in the PjBL model help improve students' science literacy skills. Students feel that PjBL helps in developing problem-solving skills, increasing learning motivation, expressing opinions, and providing experience in organizing projects. This aligns with the experience of students who feel more active during the learning process and experience improvement in their understanding and application of scientific concepts.

Additionally, students also indicate increased interest in scientific studies through PjBL. They feel that PjBL makes them more active during learning activities, encourages them to develop science skills, and helps them understand complex concepts. The role of teachers in assisting students when facing difficulties in project work is also considered very effective, enabling students to be more active in learning.

Group activities in PjBL also make students more active in asking questions and expressing opinions or ideas. They feel that working in groups allows them to ask each other questions and exchange opinions, which helps them in the learning process. Additionally, students also feel that they can easily gather information from the projects they are working on, making learning more enjoyable and effective.

Overall, students provide a very positive response to the use of PjBL in science education in high schools. They feel that this approach makes them more active, interested, and engaged in scientific learning, as well as helping them develop various skills and a deeper understanding of concepts.

Challenges in PjBL Implementation

Teachers face several challenges in implementing Project-Based Learning (PjBL) to enhance science literacy in classrooms. One of the main challenges is the lack of clarity in providing guidance on how to formulate relevant questions and problems based on presented phenomena. This can result in some student groups struggling to find underlying problems for their projects due to a lack of understanding of the presented phenomena.

Furthermore, the design of project implementation also poses a challenge, as not all teachers can formulate learning problems perfectly. Some student groups still struggle to formulate problems from the presented phenomena because they may not fully understand the phenomena or issues presented. Lack of understanding of the concepts underlying the problems also contributes to students' difficulty in providing arguments related to these concepts.

Moreover, factors such as students' quiet and lack of confidence can also make them reluctant to showcase their abilities. Additionally, the lack of comprehensive teaching materials and limited time allocation for the learning process can also lead to students' decreased enthusiasm and reduced activity in learning.

Furthermore, inadequate interaction between teachers and students is also a challenge. Although learning is student-focused, they still require better guidance to understand problems better and maintain learning quality. Therefore, teachers need to increase interaction with students to help them understand problems better and overcome challenges in implementing PjBL to enhance science literacy. Results should be clear and concise. The discussion should

explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusion

Project-Based Learning (PjBL) has proven to be an effective approach to enhancing scientific literacy among high school students by engaging them in challenging, real-world projects. This method deepens students' understanding of scientific concepts while fostering critical thinking, problem-solving, collaboration, and analytical skills. Students respond positively to PjBL, as it promotes active participation, increases motivation, and sparks an interest in science through real-world applications. Teachers play a key role in guiding and supporting students, helping them navigate challenges throughout the process. However, the implementation of PjBL faces obstacles such as limited class time, insufficient resources, and the need for well-structured projects. To overcome these challenges, schools must invest in adequate materials, allocate sufficient time, and provide teacher training to ensure effective project design and facilitation. These findings have broader implications for secondary education, as PjBL can be applied across different science subjects to foster scientific literacy and essential 21st-century skills globally. By transforming teaching methods to be more student-centered and inquiry-based, PjBL prepares students for future academic and professional success, provided there is sufficient investment in resources and teacher development.

Acknowledgments
We would like to express our sincere gratitude to the editorial team of this journal for the opportunity to publish our research. We also wish to thank the reviewers for their valuable feedback and suggestions, which have greatly enhanced the quality of this paper. Our appreciation extends to our institution for its support during the research process. Last but not least, we want to thank everyone who contributed, both directly and indirectly, to the preparation of this article. Our deepest thanks to all who played a role in the completion of this research.

Author Contributions
All authors contributed to writing this article.

Funding
This research received no external funding

Conflicts of Interest
The authors declare no conflict of interest.

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