



Abstract. *Improving scientific literacy is crucial for early childhood development, yet limited studies necessitate a thorough analysis to identify effective solutions. This study aims to analyze the implementation of project-based learning in early childhood education to improve scientific literacy. The study followed the identification, screening, eligibility assessment, and inclusion stages using a systematic literature review based on the PRISMA framework. Sources were accessed from databases such as Google Scholar, ERIC, Springer, JSTOR, Dimensions, and ScienceDirect, totalling 2085 articles. After screening articles published between 2014 and 2024, written in English, and relevant to the topic, 55 articles were selected for further analysis. The findings categorize approaches, trends, subjects, effects, and learning media used in adopting project-based learning to develop scientific literacy in early childhood. Two main approaches were identified: 1) narrative and dialogue and 2) project-based learning. Project-based learning is widely applied in 16 countries in Asia, America, Australia, and Europe. The review indicates that project-based learning improves early childhood scientific literacy in physics, biology, astronomy, and technology through learning media such as experimental tools, toys, robots, AR, VR, and AI. Therefore, implementing project-based learning supported by innovative learning media is an effective solution for improving scientific literacy in early childhood.*

Keywords: *early childhood education, literature review, project-based learning, scientific literacy*

Delfi Eliza

State University of Padang, Indonesia

Trisna Mulyeni

Jakarta State University, Indonesia

Yulsyofriend, Nenny Mahyuddin,

Yeni Erita, Muhammad Dhanil

State University of Padang, Indonesia

IMPLEMENTATION OF PROJECT-BASED LEARNING IN IMPROVING SCIENTIFIC LITERACY IN EARLY CHILDHOOD EDUCATION: SYSTEMATIC LITERATURE REVIEW

**Delfi Eliza,
Trisna Mulyeni,
Yulsyofriend,
Nenny Mahyuddin,
Yeni Erita,
Muhammad Dhanil**

Introduction

Education has a very important role in shaping individuals who can face life's challenges in the future. As the main foundation of human development, education transfers knowledge and develops skills, values, and characters that support the progress of individuals and society (Brighouse, 2024). In the modern era full of change and complexity, education is the key to preparing a generation that is critical, creative, and adaptive to various global dynamics (González-Salamanca et al., 2020). More than that, education also plays a role in creating equality of opportunity, empowering individuals from different backgrounds, and building inclusive and sustainable societies (González-Pérez & Ramírez-Montoya, 2022). Therefore, the urgency of education is not only limited to formal learning in schools but also includes the formation of relevant and future-oriented life skills.

Early childhood education is a crucial foundation in supporting the holistic development of children. At this stage, education is designed to develop early childhood cognitive, socio-emotional, and physical abilities in an integrated manner (Bracken & Theodore, 2020; Larimore, 2020). Teachers' readiness to teach is critical, especially in creating a supportive learning environment and utilizing technology to actively engage in early childhood learning (Anisimova, 2020; Yıldırım, 2021). Furthermore, early childhood education also focuses on developing speaking and literacy skills, which are essential foundations for the next stages of development (Brodin & Renblad, 2020; Hjetland et al., 2020). Early childhood are trained to think critically and creatively at this stage, enabling them to grow and develop holistically while acquiring relevant skills for the future (Askarov, 2022; Joo et al., 2020). In this context, education is the primary foundation for producing individuals capable of addressing global challenges and leveraging available opportunities.



In building early childhood abilities and supporting their structured development, the project-based learning model is aligned with their developmental needs. This learning approach is designed to holistically address the developmental demands of children (Admawati et al., 2018). Project-based learning is regarded as highly relevant to meeting the demands of 21st-century education, as it enables early childhood to understand theory and apply it in real-world situations (Guo et al., 2020). Project-based learning helps students become creative and adaptive problem solvers in line with the demands of the modern world (Almulla, 2020). Project-based learning emphasizes an investigative process through real-world projects designed to solve specific problems. The urgency of implementing project-based learning lies in its ability to bridge the gap between traditional theoretical learning and the real-world needs of society and the workforce (Kokotsaki et al., 2016). This approach has proven effective in developing 21st-century skills, including critical thinking, creativity, communication, and scientific literacy (Hawari & Noor, 2020).

Scientific literacy is the ability to investigate, interpret, and explain scientific phenomena based on issues and occurrences in the surrounding environment (PISA, 2023). This ability helps individuals understand scientific concepts and apply them in everyday life to make evidence-based decisions (Valladares, 2021). As one of the key competencies of the 21st century, scientific literacy plays a crucial role in shaping critical and scientific thinking, which is essential for addressing increasingly complex global challenges (Aristeidou & Herodotou, 2020). One effective approach to supporting the development of scientific literacy is the integration of project-based learning. This method provides early childhood learning opportunities through direct exploration and activities relevant to their lives (Weng et al., 2020). In project-based learning, early childhood design and conduct projects related to real-world scientific phenomena (Mursid et al., 2022). Through this approach, they acquire scientific knowledge and enhance collaboration, communication, and problem-solving skills.

Project-based learning has been widely implemented to support the development of scientific literacy across various educational levels, including elementary schools, secondary schools, and higher education. Numerous studies have demonstrated the positive effects of this approach on scientific literacy. At the elementary level, project-based learning helps students develop scientific literacy skills such as writing scientific reports (Afriana et al., 2016; Alemneh & Gebrie, 2024) and thinking creatively to solve scientific problems (Saad & Zainudin, 2022). At the secondary level, this approach significantly enhances students' understanding of scientific concepts and their ability to solve science-based problems (Afriana et al., 2016; Maros et al., 2023; Zhao & Wang, 2022). Meanwhile, in higher education, project-based learning aids students in reconstructing scientific knowledge through real-world problem-solving and improves learning outcomes relevant to scientific literacy (Crespi et al., 2022; Miller & Krajcik, 2019; Shin et al., 2021).

Project-based learning has been proven effective in developing scientific literacy across various educational levels. However, its application in early childhood education remains underexplored. This gap highlights a lack of understanding regarding the best practices for integrating this approach at a critical stage for building foundational skills in early childhood. Scientific literacy is a fundamental skill for early childhood, and it helps early children understand their environment, living organisms, technology, and natural phenomena. The limitations of previous research in presenting information that analyzes the effects, trends, and supporting resources for project-based learning in improving science literacy in early childhood indicate a significant research gap. Studying these variables offers a unique contribution by presenting innovations relevant to researchers and decision-makers in early childhood education. Therefore, A Systematic Literature Review (SLR) is needed as an initial step to identify relevant prior findings and uncover research trends. Through this systematic analysis, trends and the impact of project-based learning implementation can be more precisely identified, particularly regarding its application in improving scientific literacy in early childhood.

Research Aim and Research Questions

This study has aimed to explore critical aspects not fully addressed in previous analyses, particularly concerning the trends and effectiveness of approaches to developing scientific literacy in early childhood. Most prior studies focus on the outcomes of project-based learning implementation at higher educational levels, while analysis of its application in early childhood education remains limited. As a recognized effective model for supporting scientific literacy, project-based learning requires further investigation in the context of early childhood education, especially across different countries, to understand its adaptations and challenges. This literature review has aimed to examine learning approaches that support improving scientific literacy, specifically investigating the impact of



project-based learning on early childhood. There were four research questions (RQ) that have been formulated to guide the implementation of this research,

1. What approaches are applied to support scientific literacy in early childhood education?
2. What are the trends in project-based learning approaches in supporting scientific literacy in early childhood education?
3. Is project-based learning effective in improving scientific literacy in early childhood education?
4. What is the learning media that supports early childhood learning?

Research Methodology

This systematic literature review applies the preferred reporting items for systematic reviews and meta-analyses (PRISMA) method to identify, screen, and collect studies for analysis. This literature review process includes identification, screening, eligibility, and inclusion (Dhanil & Mufit, 2024; Moher et al., 2009). Overall, the research analyzes 2085 articles focusing on the implications of learning in improving scientific literacy.

Identification

The studies were identified through several databases, including Google Scholar, ERIC, ScienceDirect, JSTOR, Dimensions, and Springer. Data were collected using keywords such as early childhood, preschool, kindergarten, project-based learning, and scientific literacy. These keyword combinations were applied to optimize the search and find relevant studies. In further searches, keywords were combined using the "OR" and "AND" operators. The keywords identified in the titles and abstracts of articles were used. The search operator applied was ("Kindergarten" OR "Early Childhood" OR "Preschool") AND ("Project-Based Learning" OR "PjBL") AND ("Scientific Literacy" OR "Science Literacy") to generate articles focused on relevant studies. The identification results showed that there were 51 studies from Google Scholar, 102 from ScienceDirect, 1,024 from Springer, 56 from JSTOR, 845 from Dimensions, and 7 from ERIC.

Screening

The study was collected by applying keywords across various databases with a systematic screening step. Screening was conducted using inclusion and exclusion criteria to ensure that only relevant studies were retained. Studies that passed the screening must contain specific information aligned with the keywords used, which were identified in the titles and abstracts of the articles. Additionally, the screening was limited to articles published between 2014 and 2024, written in English, and categorized as scientific journal articles. The screening steps aimed to improve the accuracy of selecting studies that align with the research focus. The entire process was systematically documented and presented in Table 1.

Table 1
Screening Process

Criteria	Inclusion	Exclusion
Year	2014-2024	Not within the year range of 2014 to 2024.
Type	Article	The research file type does not include conferences, book chapters, theses, etc.
Language	English	Not written in English.
Scientific Journal Rankings (Q)	Q1-Q4	The journal where the article was published is not included in the Scopus ranking (Q)

Based on the applied screening criteria, 400 articles met the inclusion criteria. These articles were published between 2014 and 2024, were written in English, and are categorized as journal articles included in the Scopus rankings. Non-English literature and conference papers were excluded to ensure the quality and consistency of the sources used in this study. Non-English literature often faces accessibility challenges, such as limitations in translation that may affect data interpretation. While potentially offering valuable insights, conference papers

often lack the rigorous peer-review process required to ensure consistency in quality and validity. Therefore, this analysis included only English-language literature published in peer-reviewed journals to uphold methodological accuracy and maintain research credibility.

Furthermore, the selected articles were published in journals indexed in the Scopus ranking system, with quartile distributions as follows: Q1 (quartile > 75%), Q2 ($50\% \leq \text{quartile} \leq 74\%$), Q3 ($25\% \leq \text{quartile} \leq 49\%$), and Q4 (quartile $\leq 24\%$). Articles were selected from journals indexed by quartile rankings to ensure high publication quality and comprehensive data availability. The screening results were then assessed for feasibility, with further selection to ensure the chosen studies were high quality. Articles that met the quality criteria were then considered suitable for analysis. This process ensured that only articles meeting the research standards were used in further analysis.

Eligibility and Included

The initial screening stage identified 220 articles deemed relevant for further analysis. In the second stage, 165 articles were excluded based on predefined eligibility criteria. During this phase, a comprehensive evaluation was conducted to ensure that the remaining articles met the detailed requirements. The assessment involved evaluating the articles against several criteria, including the context of the study, the clarity of research objectives, the methodology employed, and the robustness of the research findings. These detailed evaluation criteria are systematically outlined and summarized in Table 2.

Table 2
The Criteria Quality Assessment of Articles

No	Criteria	Descriptions
1	Study context	Does the article clearly explain the research plan, implementation, and development?
2	Objectives and purposes	Are the research objectives described in detail?
3	Methodology	Does the methodology section elaborate on the research design, sample, data collection procedures, data analysis, and interpretation?
4	Research Result	Are the data presented and thoroughly analyzed?

The article evaluation process was conducted using clear criteria to ensure the quality and relevance of the articles analyzed. Each article that met the criteria was assigned a score based on four main aspects: study context, research purpose, methodology, and research results. The evaluation was carried out using a scale of 1 to 4, with the following breakdown: a score of 1 indicated that the criteria were not met, a score of 2 indicated that the criteria were almost met, a score of 3 indicated that the criteria were met, and a score of 4 indicated that the criteria exceeded the established standards. After the analysis, each article could receive a maximum score of 16 if all criteria were met with the highest score or a minimum score of 4 if no criteria were met. Articles with a score of less than 8 were excluded from further analysis. The article quality evaluation was conducted using criteria summarized in Table 3.

Table 3
Quality Assessment

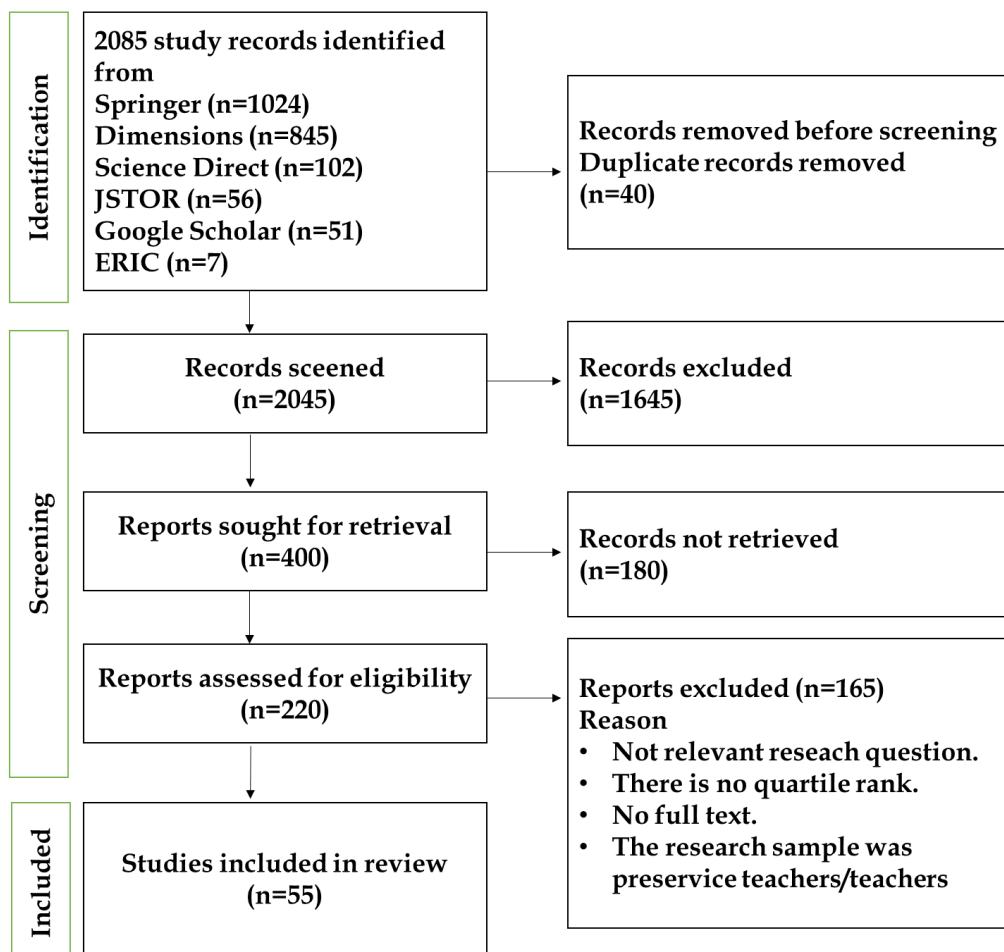
Criteria	The problem, objective, rationale, and research questions are clearly articulated (Score 4)	The problem, objective, rationale, and research questions are adequately articulated (Score 3)	The problem, objective, rationale, and research questions are poorly articulated (Score 2)	The problem, objective, rationale, and research questions are incomplete (Score 1)
Study context	Fully explained the theoretical framework	The theoretical framework is explained clearly	The theoretical framework is explained generally and lacks detail	Theoretical framework not explained
Objectives and purposes	Research objectives explained in detail	Research objectives explained clearly	Research objectives are explained generally without detail	Research objectives not explained

Criteria	The problem, objective, rationale, and research questions are clearly articulated (Score 4)	The problem, objective, rationale, and research questions are adequately articulated (Score 3)	The problem, objective, rationale, and research questions are poorly articulated (Score 2)	The problem, objective, rationale, and research questions are incomplete (Score 1)
Methodology	Research design, sample, data collection procedures, data analysis, and validation are fully explained.	Research design, sample, data collection procedures, and data analysis are explained without detailed validation.	Research design, sample, and data collection are explained with limited detail, with no data analysis or validation.	Research design, sample, data collection procedures, data analysis, and validation are not fully explained.
Research Result	Data and research results are fully explained	Data and research results are explained clearly	Data explained generally without detailed analysis of results	Data and research results not fully explained

Table 3 presents the four main criteria used to assess the quality of the articles. This assessment was designed to minimize potential biases in the article analysis. The evaluation results showed that 55 articles were considered to meet the evaluation standards and were deemed suitable for further analysis. This selection was systematically based on the established eligibility criteria to ensure that only relevant and high-quality articles were included. All stages of the article identification and selection process followed the PRISMA method, which is detailed in Figure 1.

Figure 1

The Stages of Research Through The PRISMA Stages.



Data Extraction and Content Analysis

The research data were obtained from several databases, including Google Scholar, ERIC, ScienceDirect, JSTOR, Dimensions, and Springer, with a total of 2048 articles. The screening process was conducted in stages, resulting in 55 articles that met the criteria for review. The selected articles were from high-reputation journals indexed in Scopus. The results of this analysis are presented in various sections, covering the research methods and the focus of the data sources obtained. The data were categorized based on factors such as authors, publication year, journal, quartile ranking (Q), and the country where the research was implemented, as detailed in Table 4.

Table 4
Data Extraction

Author	Year	Journal	Q	Countrysy
(Kaehler et al., 2020)	2020	International Journal of Science Education	Q1	Germany
(Booth et al., 2022)	2022	Developmental Psychology	Q1	USA
(Pereira et al., 2020)	2020	Early Child Development and Care	Q2	Portugal
(Buchholz & Pyles, 2018)	2018	Reading Teacher	Q1	USA
(Beasley et al., 2021)	2021	International Journal of Early Childhood	Q1	Australia
(Booth et al., 2020)	2020	Developmental Psychology	Q1	USA
(Gray et al., 2022)	2022	Journal of Research on Educational Effectiveness	Q1	USA
(Kumar et al., 2024)	2024	Mind, Brain, and Education	Q2	USA
(Wight et al., 2016)	2016	Environmental Education Research	Q1	USA
(Greca Dufranc et al., 2020)	2020	European Journal of STEM Education	Q2	Spain
(Dale Tunnicliffe & Gkouskou, 2020)	2020	Early Child Development and Care	Q2	USA
(McNerney et al., 2020)	2020	Early Child Development and Care	Q2	UK
(Ahi, 2017)	2017	Cogent Education	Q2	Turkey
(Koerber & Osterhaus, 2019)	2019	Journal of Cognition and Development	Q2	Germany
(Nevo & Vaknin-Nusbaum, 2018)	2018	Reading Psychology	Q1	Israel
(Wright & Gotwals, 2017)	2017	Elementary School Journal	Q1	USA
(Paños & RuizGallardo, 2021)	2021	Journal of Research in Science Teaching	Q1	Spain
(de Brito Miranda et al., 2017)	2017	Early Child Development and Care	Q1	Brazil
(Impedovo et al., 2017)	2017	Research in Science Education	Q1	France
(Cascarosa et al., 2022)	2022	Journal of Biological Education	Q2	Spain
(Connor et al., 2017)	2017	Journal of Educational Psychology	Q1	USA
(Doshi et al., 2024)	2024	Learning and Individual Differences	Q1	Germany
(Bauer & Booth, 2019)	2019	Early Childhood Research Quarterly	Q1	USA
(Junge et al., 2021)	2021	Early Childhood Research Quarterly	Q1	Germany
(Lazaroff & Vlach, 2022)	2022	Journal of Experimental Child Psychology	Q1	USA
(Fragkiadaki et al., 2024)	2024	Research in Science Education	Q1	Australia
(García-González & Schenetti, 2022)	2022	Journal of Outdoor and Environmental Education	Q3	Spain
(Fragkiadaki et al., 2023)	2023	Research in Science Education	Q1	Australia
(Koerber & Osterhaus, 2021)	2021	Unterrichtswissenschaft	Q3	Germany
(Havu-Nuutinen et al., 2022)	2022	Research in Science Education	Q1	Finland
(Hsin & Wu, 2023)	2023	Research in Science Education	Q1	PRC
(Adbo & Vidal Carulla, 2020)	2020	International Journal of Early Childhood	Q4	Sweden
(Saçkes et al., 2020)	2020	International Journal of Early Childhood	Q1	Sweden



Author	Year	Journal	Q	Countsrty
(Ennes et al., 2023)	2023	Research in Science Education	Q1	USA
(Allen et al., 2021)	2021	Research in Science Education	Q2	UK
(Alan & Erdoğan, 2018)	2018	Early Childhood Education Journal	Q1	Turkey
(Ampartzaki & Kalogiannakis, 2016)	2016	Early Childhood Education Journal	Q2	Greece
(Hsin & Wu, 2023)	2023	Research in science education	Q1	PRC
(Cherniak et al., 2019)	2019	Journal of Early Childhood Research	Q2	USA
(Zhou & Yang, 2024)	2024	Early Childhood Education Journal	Q1	PRC
(Güley & Keskinliç, 2024)	2024	Humanities and social sciences communications	Q1	Turkey
(Hu, 2022)	2022	Journal of outdoor and environmental education	Q3	PRC
(Parwoto et al., 2024)	2024	International journal of music education	Q3	Indonesia
(Can et al., 2017)	2017	Journal of Baltic Science Education,	Q2	Turkey
(Başaran & Bay, 2023)	2023	Early Child Development and Care	Q1	Turkey
(Oranç & Küntay, 2019)	2019	International Journal of Child-Computer Interaction	Q1	Turkey
(Yilmaz, 2016)	2016	Computers in human behavior	Q1	Turkey
(R. W. Chen & Chan, 2019)	2019	Journal of Educational Computing	Q1	PRC
(Gecu-Parmaksiz & Delialioğlu, 2019)	2019	British Journal of Educational Technology	Q1	Turkey
(Kokkalia & Drigas, 2016)	2016	International journal of interactive mobile technologies	Q2	PRC
(Belda-Medina & Marrahi-Gomez, 2023)	2023	Electronics	Q2	Spain
(Lorusso et al., 2020)	2020	Applied Sciences	Q2	Italy
(Kusuma et al., 2018)	2018	International journal of interactive mobile technologies	Q2	Indonesia
(Passig et al., 2016)	2016	Computers & Education	Q1	Israel
(Su & Yang, 2024)	2024	Interactive Learning Environments	Q1	PRC

Table 4 presents the results of the studies included in the review process. The data includes journals indexed in Scopus with quartile rankings of Q1 (34 articles), Q2 (16 articles), Q3 (4 articles), and Q4 (1 article). These articles are distributed across 16 countries: Germany, the United States of America (USA), Portugal, Australia, Spain, the United Kingdom (UK), Turkey, Israel, Brazil, France, Finland, Taiwan, Sweden, Greece, People's Republic of China (PRC), and Indonesia. The distribution of articles by year range is as follows: 2014–2016 (5 articles), 2017–2019 (16 articles), 2020–2022 (21 articles), and 2023–2024 (13 articles). This information is crucial in investigating the trends in implementing project-based learning to improve scientific literacy abilities in early childhood education contexts. The extraction results from the approaches, science learning subjects, learning media, and findings from the analyzed articles are presented in Table 5.

Table 5
Content Analysis

Author	Approach	Subject	Finding	Learning Media
(Kaehler et al., 2020)	Narrative and dialogue	Biology	Teaching science terminology helps children improve their scientific literacy from an early age.	Book
(Booth et al., 2022)	Project	Physics	Project-based inquiry learning supports exploration in improving early childhood scientific literacy.	Toy
(Pereira et al., 2020)	Project	Physics	Hands-on work is effective in teaching science in early childhood.	Toy
(Buchholz & Pyles, 2018)	Project	Biology	Early childhood are assigned tasks to explore the zoo and redraw the animals they observe, improving their science abilities.	Experimental Tool

Author	Approach	Subject	Finding	Learning Media
(Beasley et al., 2021)	Project	Biology	Assigning early childhood tasks in plant exploration enhances their knowledge, curiosity, and scientific literacy.	Experimental Tool
(Booth et al., 2020)	Narrative and dialogue	Physics	Through question-and-answer activities, early childhood's ability to explain phenomena can improve.	Book
(Gray et al., 2022)	Project	Biology	Early children are given projects to write and illustrate animals at the zoo, which helps improve their scientific literacy abilities.	Experimental Tool
(Kumar et al., 2024)	Narrative and dialogue	Biology	Interaction and conversation between teachers and children support the enhancement of scientific literacy.	Book
(Wight et al., 2016)	Project	Physics	Task-based activities through exploring science tools support early childhood scientific literacy abilities.	Toy
(Greca Dufranc et al., 2020)	Project	Technology	Integrating learning by assembling robots helps early childhood improve their understanding of scientific literacy related to technological development.	Robot
(Dale Tunnicliffe & Gkouskou, 2020)	Narrative and dialogue	Technology	Play activities and communication in learning help children learn science more enjoyably.	Book
(McNerney et al., 2020)	Narrative and dialogue	Biology	Play activities and question-and-answer sessions between children and teachers help improve early childhood scientific literacy abilities.	Book
(Ahi, 2017)	Project	Biology	Project-based learning in assembling a digestive system puzzle helps children improve their scientific literacy.	Toy
(Koerber & Osterhaus, 2019)	Narrative and dialogue	Biology	Scientific thinking is influenced by intelligence and language in supporting the enhancement of early childhood scientific literacy.	Book
(Nevo & VakninNusbaum, 2018)	Narrative and dialogue	Biology	Science text-based programs help improve early childhood scientific vocabulary.	Book
(Wright & Gotwals, 2017)	Narrative and dialogue	Physics	Early childhood scientific abilities increase through communication processes during learning.	Book
(Paños & Ruiz-Gallardo, 2021)	Narrative and dialogue	Physics	Attitudes towards learning through interaction and communication positively impact science learning.	Book
(de Brito Miranda et al., 2017)	Project	Biology	Through project activities, early childhood understands the importance of caring for animals and life.	Toy
(Impedovo et al., 2017)	Project	Physics	Understanding the formation of shadows is acquired through tasks involving early childhood observing various types of shadows from different objects.	Experimental Tool
(Cascarosa et al., 2022)	Project	Physics	Magnifying glasses help children observe animals more clearly.	Experimental Tool
(Connor et al., 2017)	Narrative and dialogue	Physics	Activities and social interactions contribute to improvement in early childhood science knowledge.	Book
(Doshi et al., 2024)	Project	Physics	Project-based learning is effective in improving early childhood scientific literacy.	Experimental Tool
(Bauer & Booth, 2019)	Narrative and dialogue	Physics	Communication activities support early childhood in learning science more effectively.	Book
(Junge et al., 2021)	Narrative and dialogue	Physics	Parental involvement has a positive impact on early childhood science knowledge.	Book
(Lazaroff & Vlach, 2022)	Narrative and dialogue	Physics	Introducing scientific vocabulary aids in the conceptual development of early childhood science understanding.	Book
(Fragkiadaki et al., 2024)	Project	Physics	Through Project-based learning activities, children develop an understanding of light and shadows while improving their scientific literacy.	Toy
(GarcíaGonzález & Schenetti, 2022)	Project	Biology	Learning activities that involve environmental exploration foster ecological awareness and improve scientific literacy in early childhood	Toy
(Fragkiadaki et al., 2023)	Project	Biology	Play-based learning activities help early childhood develop scientific abilities naturally.	Toy



Author	Approach	Subject	Finding	Learning Media
(Koerber & Osterhaus, 2021)	Narrative and dialogue	Physics	The content presented in books provides important support for early childhood students to study science in a more structured way.	Book
(HavuNuutinen et al., 2022)	Project	Biology	Project-based science learning is not effective in supporting early childhood understanding of using toys.	Toy
(Hsin & Wu, 2023)	Narrative and dialogue	Physics	Learning modules support early childhood scientific practices in studying science effectively.	Book
(Adbo & Vidal Carulla, 2020)	Narrative and dialogue	Chemistry	Conversations between children and teachers help reinforce the understanding of scientific concepts.	Book
(Saçkes et al., 2020)	Project	Physics	Project-based learning and experiments significantly improve early childhood science abilities.	Experimental Tool
(Ennes et al., 2023)	Project	Physics	Limitations in science equipment can hinder the development of early childhood's ability to understand scientific concepts.	Experimental Tool
(Allen et al., 2021)	Project	Biology	Science learning through tasks like individually measuring body mass and reporting helps train early childhood scientific abilities.	Experimental Tool
(Alan & Erdoğan, 2018)	Narrative and dialogue	Biology	Introducing living creatures through dinosaur stories helps improve early childhood scientific literacy.	Book
(Ampartzaki & Kalo-giannakis, 2016)	Project	Astronomy	Project-based learning in constructing the solar system supports a deeper understanding of science.	Experimental Tool
(Hsin & Wu, 2023)	Project	Physics	Introducing tools through images as a guide to completing tasks enhances early childhood scientific literacy abilities.	Experimental Tool
(Cherniak et al., 2019)	Project	Technology	Assigning tasks for children to design a robot together supports the development of scientific thinking.	Robot
(Zhou & Yang, 2024)	Narrative and dialogue	Biology	Project-based learning helps early childhood learners understand concepts through stories, enhancing their scientific literacy.	Book
(Güley & Keskinliç, 2024)	Project	Physics	Project-based learning supports children in better understanding scientific terms.	Experimental Tool
(Hu, 2022)	Project	Biology	Project-based learning that utilizes nature journals supports holistic learning experiences while enhancing early childhood science abilities.	Experimental Tool
(Parwoto et al., 2024)	Project	Technology	Collaborative Project-based learning significantly boosts early childhood creativity and scientific literacy abilities.	Robot
(Oranç & Küntay, 2019)	Project	Physics	Implementing AR in project-based learning helps students connect scientific phenomena with real-world contexts.	AR
(Yilmaz, 2016)	Project	Biology	Early childhoods are assigned to assemble a puzzle resembling an AR object displayed when learning about plant shapes.	AR
(R. W. Chen & Chan, 2019)	Project	Technology	Early childhoods are given a project to create flashcards to recognize object names with the help of AR.	AR
(GeculParmaksiz & Delialioğlu, 2019)	Project	Physics	AR technology is used to assist children in identifying objects through matching tasks.	AR
(GeculParmaksiz & Delialioğlu, 2019)	Project	Physics	No significant differences were found between early childhood learning with AR and those using traditional learning methods in completing projects to recognize various object shapes.	AR
(Kokkalia & Drigas, 2016)	Project	Technology	The implementation of AR technology helps early childhoods recognize new vocabulary related to objects.	AR
(Lorusso et al., 2020)	Project	Biology	VR technology helps children recognize living creatures through exploration in a virtual environment.	VR
(Belda-Medina & Marrahi-Gomez, 2023)	Project	Technology	Learning using AR technology helps train children to develop the ability to recognize scientific terms.	AR



Author	Approach	Subject	Finding	Learning Media
(Lorusso et al., 2020)	Project	Technology	When applied in project-based learning, VR helps improve early childhood ability to recognize technology.	VR
(Kusuma et al., 2018)	Project	Biology	VR technology helps early childhoods recognize the names of fish in the context of science learning.	VR
(Passig et al., 2016)	Project	Technology	The implementation of VR effectively enhances early childhood cognitive abilities.	VR
(Su & Yang, 2024)	Project	Technology	Early childhoods can draw with the help of AI technology.	AI

The recommendations that can be proposed include implementing learning with project-based, narrative, and dialogic approaches, as well as their application in other areas of science competency. This approach aims to improve students’ understanding and scientific literacy abilities through more interactive and context-based methods. Additionally, the implementation of innovative and up-to-date learning media, such as books, toys, experimental tools, robots, Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI), serves as an effective alternative to support interactive learning for early childhoods. These technologies can enrich the learning experience, motivate students, and create a more engaging and enjoyable learning environment. However, the results show several effects, both positive and negative, and no effects in the implementation of project-based learning in improving scientific literacy in early childhood.

Research Results

Approaches Applied to Support Scientific Literacy in Early Childhood Education

Two main learning approaches were categorized based on the analysis of the study results. This categorization was grounded in the specific implementation processes to improve scientific literacy in early childhood education. The first approach, project-based learning, was widely applied to improve early childhood scientific literacy through hands-on projects. The second approach involved narrative and dialogue-based learning, emphasizing storytelling and interactive discussions to engage young learners in scientific concepts. This analysis highlighted some studies that supported these approaches, demonstrating the widespread adoption of both methods, as shown in Figure 2.

Figure 2
The Distribution of Approaches Applied in Early Childhood Education.

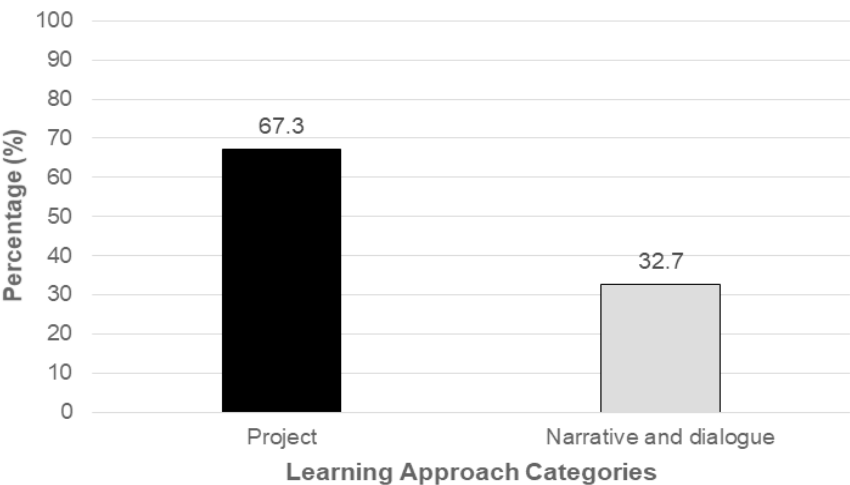


Figure 2 shows two categories of learning approaches used to improve scientific literacy abilities in early childhood. The narrative and dialogue-based approach was applied in 32.7% of the studies (18 articles), while the

project-based learning approach was used in 67.3% (37 articles). The narration and dialogue approach introduces early childhood to new scientific terms through stories and dialogic interactions between teachers and early childhood. Through this approach, early childhood expands their scientific vocabulary and deepens their understanding of scientific concepts. Teachers act as facilitators who guide active dialogue to help children connect scientific concepts with their everyday lives.

Meanwhile, the project-based learning approach engages early childhood in hands-on activities like completing project-based tasks. This approach focuses on child-centred learning, where early childhoods actively explore, investigate, and explain scientific concepts through direct experiences. They are also given opportunities to report the results of tasks or experiments they have completed to their teachers, thus strengthening their communication and critical thinking skills. These two approaches complement each other to improve early childhood scientific literacy, with narrative and dialogue providing a foundation for understanding. At the same time, projects and experiments strengthen practical skills through real-life experiences.

Trends in Project-Based Learning Approaches in Supporting Scientific Literacy in Early Childhood Education

Based on a literature search in international academic databases indexed in Scopus, 2048 articles discussing scientific literacy were found from 2014 to 2024. The quality of the studies was assessed based on their publication in reputable journals, with the Scopus quartile ranking serving as the primary indicator. From the collected data, 37 articles were specifically focused on project-based learning to enhance scientific literacy in early childhood, published in Scopus-indexed journals over the past 10 years. The distribution of these articles is visualized in Figure 3.

Figure 3

The Distribution of The Quartile Ranking of Articles Indexed in Scopus

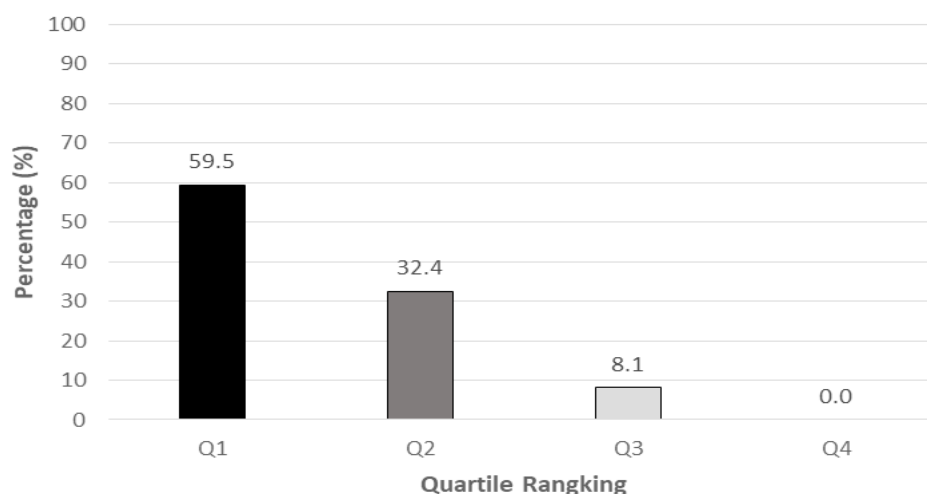


Figure 3 shows the distribution of studies discussing project-based learning published in high-quality journals indexed in Scopus, categorized based on quartile rankings. The distribution of studies on project-based learning implementation in quartile rankings is as follows: Q1 was used in 59.5% of the studies (22 articles), Q2 was used in 32.4% of the studies (12 articles), Q3 was used in 8.1% of the studies (3 articles), and Q4 was used in 0% of the studies (0 articles). These results indicate that studies on project-based learning are still relatively rare in reputable journals, suggesting opportunities for further, more comprehensive investigations, particularly in implementing project-based learning to enhance scientific literacy in early childhood. The study results are further analyzed by grouping the research locations based on the countries where they were conducted. This review shows the geographical distribution of project-based learning implementation in early childhood education. Several countries have investigated this approach to identify trends and opportunities in supporting the development of scientific literacy from an early age. The distribution of articles by country is presented in Figure 4.



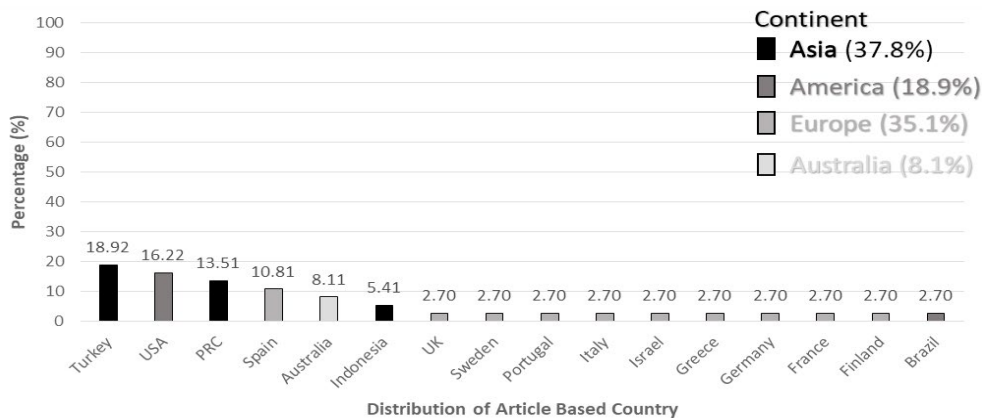
Figure 4*Distribution of Articles in Each Country*

Figure 4 shows the distribution of studies on implementing project-based learning to improve scientific literacy in early childhood education across various countries. The distribution of the analyzed studies is spread across four continents, with Asia contributing 37.8%, Europe 35.1%, America 18.9%, and Australia 8.1%. Among the countries, Turkey has the highest number of articles, with 18.9% (7 articles). The USA ranks second with 16.2% (6 articles). The PRC contributes 13.5% (5 articles), followed by Spain with 10.8% (4 articles). Australia produces 8.1% (3 articles), while Indonesia has 5.4% (2 articles). Other countries such as the UK, Sweden, Portugal, Italy, Israel, Greece, Germany, France, Finland, and Brazil each contribute 2.7% (1 article) of the total. These findings suggest that the application of project-based learning to improve scientific literacy in early childhood is still developing. This discovery opens opportunities for further research in various countries to understand the deeper impacts of implementing project-based learning in early childhood education.

Effects of Project-Based Learning in Improving Scientific Literacy in Early Childhood Education

The effects of project-based learning were analyzed from 37 articles discussing implementing project-based learning to improve scientific literacy in early childhood education. Overall, project-based learning applied to early childhood education was reported to have a positive effect. This approach has proven effective in improving scientific literacy through structured activities relevant to daily life. The studies analyzed indicate that project-based learning significantly improves scientific literacy in early childhood. The detailed results of the effects of project-based learning in improving scientific literacy in early childhood are presented in Figure 5.

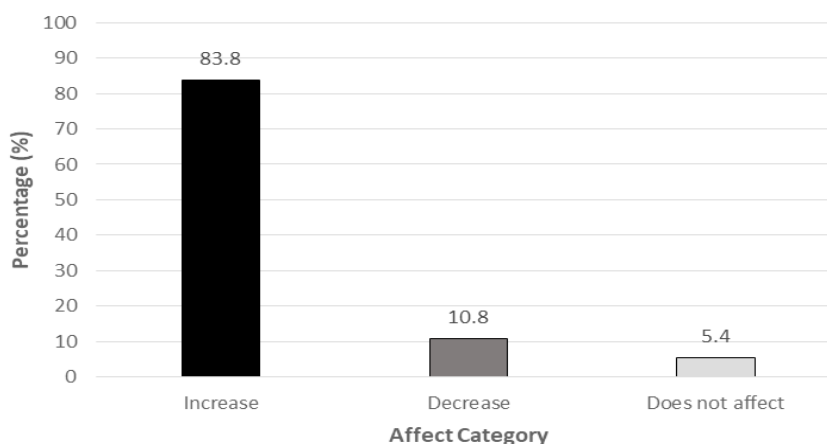
Figure 5*Distribution of Project-Based Learning Effects in Early Childhood Education*

Figure 5 displays the classification of the effects of implementing project-based learning to improve scientific literacy in early childhood education. Overall, the studies analyzed report an 83.8% positive effect (31 articles) in increasing scientific literacy in early childhood, a 10.8% negative effect (4 articles), and a 5.4% no effect (2 articles) on scientific literacy in early childhood. Project-based learning has a negative impact and leads to a decline in science literacy among children caused by the suboptimal implementation of the learning process. Limited resources, such as inadequate learning support facilities, further hinder the application of project-based learning. Inappropriate learning media that do not align with the needs of early childhood learners can reduce the quality of learning and negatively impact early childhood scientific literacy. Moreover, teachers' failure to implement the project-based learning approach and manage the learning process significantly affects early childhood success in improving their scientific literacy abilities. Teachers who are unprepared to design systematic project-based learning often fail to achieve optimal outcomes. Proper preparation by teachers is crucial to ensuring the success of project-based learning. Teachers must provide relevant learning media, supportive teaching materials, adequate resources, and systematic lesson planning, all of which are key to maintaining a focus on developing scientific literacy abilities.

Early childhood scientific literacy is generally categorized based on science subjects, such as physics, biology, astronomy, and technology. Teachers who can direct learning by focusing on these subjects will help students achieve learning objectives effectively and in a structured manner. The categorization of these studies is based on the scientific subjects that are the main topics in the learning process. The detailed results of the categorization based on study subjects are presented in Figure 6.

Figure 6

Distribution of Subjects Applied to Early Childhood Education

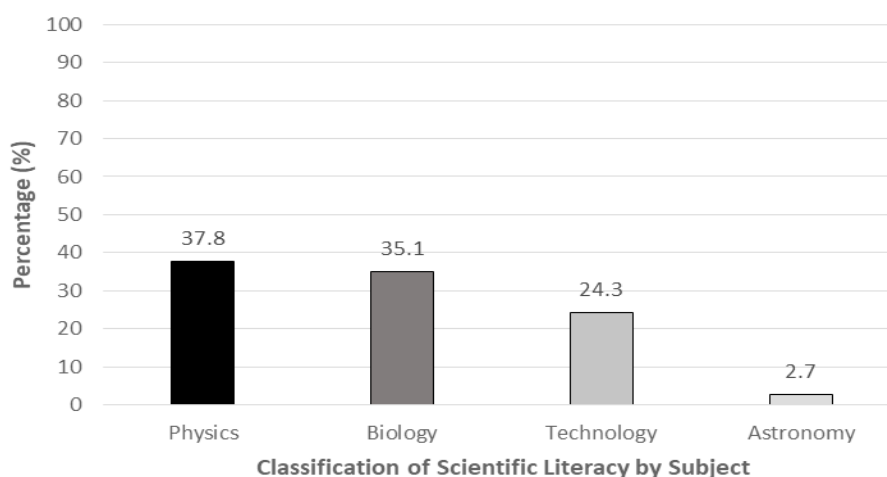


Figure 6 presents the classification of project-based learning in improving scientific literacy in early childhood education. The positive effects of implementing project-based learning on improving scientific literacy are distributed across four main study subjects: astronomy, technology, biology, and physics. Scientific literacy in astronomy relates to the study of celestial bodies. The distribution of research shows that the implementation of project-based learning in physics accounts for 37.8% (14 articles), in biology for 35.1% (13 articles), in technology for 24.3% (9 articles), and in astronomy for 2.7% (1 article). In general, the application of project-based learning has a positive impact on improving early childhood scientific literacy. Specifically, physics has become one of the main focuses due to its strong connection with explaining natural phenomena and utilizing experimental tools.

Learning Media that Supports Learning Applied in Supporting Scientific Literacy in Early Childhood

The analysis of the implementation of learning media to support scientific literacy improvement identified 37 articles reporting this information. These learning media varied in their support for scientific literacy analysis. The findings revealed different types of learning media used to enhance scientific literacy. The learning media utilized in the learning process are presented in Figure 7.



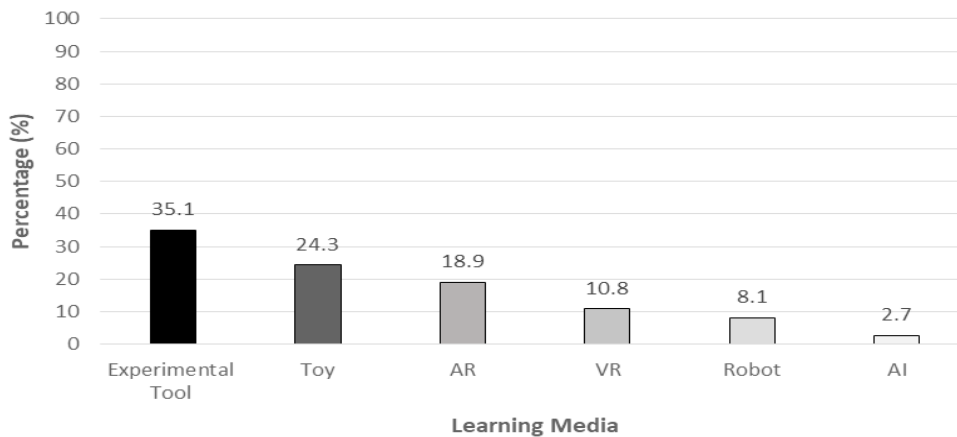
Figure 7*The Distribution of Learning Media Applied to Early Childhood Education*

Figure 7 shows six types of learning media commonly used to support learning in early childhood education. These learning media include experimental tools with 35.1% (13 articles), toys with 24.3% (9 articles), AR with 18.9% (7 articles), VR with 10.8% (4 articles), robots with 8.1% (3 articles), and AI with 2.7% (1 article). Overall, AR, VR, and AI-based learning media have the potential for recommendation in their implementation to support early childhood literacy development. Because learning media based on AR, VR, and AI technology are still slightly implemented in early childhood education

Discussion

This study uncovered several new findings from the literature analysis on literacy abilities in early childhood. The analysis reports the orientation of learning for early childhood education for researchers. In early childhood education, approaches, subjects, effects, and learning media were applied to support scientific literacy abilities in early childhood. A comprehensive and rigorous article collection process was conducted to obtain high-quality analysis results from the literature study and collect data from various diverse database sources to improve the generalization of findings and minimize the potential for bias in article selection. Analyzing articles from Scopus-indexed databases is one solution for obtaining quality data sources for analysis (Aravantinos et al., 2024). However, this study also acknowledges the various bias factors that may affect the results. One limitation of this study is the lack of input from stakeholders, such as educators and policymakers, which may limit the relevance of applying the research in real-world contexts. Future research will include in-depth interviews with educators and policymakers to integrate their practical perspectives, making the findings more applicable and relevant. Nevertheless, overall, the results of this analysis provide new directions in supporting early childhood education, complementing the limitations of previous analyses.

The main approaches that have been proven effective in supporting the development of scientific literacy in early childhood include narrative and dialogue, as well as project-based learning. The narration and dialogue-based approach emphasizes introducing scientific vocabulary through direct interactions, such as reading stories, discussing, or exploring natural phenomena. Gradually introducing scientific terminology allows children to understand fundamental scientific concepts, which are essential foundations for scientific thinking (Kaehler et al., 2020). Structured conversations between teachers and early childhood during narration and dialogue-based learning significantly improve verbal skills and the understanding of scientific concepts in early childhood (Alzahrani, 2020; Eliza et al., 2022).

Meanwhile, the project-based and experimental approach provides opportunities for children to investigate, experiment, and solve problems through hands-on experiences. Children involved in project-based learning activities demonstrate a better understanding of scientific phenomena than those who only learn through text-based education (S.-Y. Chen et al., 2022). Moreover, this approach strengthens early childhood critical thinking skills and curiosity in understanding scientific concepts. In a different context, Zhao and Wang (2022) highlight that science-based educational games can improve early childhood learning motivation and active engagement in the learning process. In general, the narrative and dialogue approach and the project-based learning approach contribute to improving scientific literacy in early childhood education.

The literature analysis on the trends of project-based learning in early childhood education reveals 37 relevant studies that form the basis for understanding the effectiveness of this approach, particularly in improving scientific literacy.

These studies reflect significant developments in adopting project-based learning for early childhood, especially in the past decade. They are relatively new in the realm of international journal publications. The research analyzed comes from reputable journals with quartile rankings of Q1 to Q3, reflecting the quality and validity of the findings. This phenomenon highlights the urgency of active, collaborative, and exploration-based learning approaches, which have been proven to support the development of cognitive, social, and scientific literacy abilities in early childhood (S.-Y. Chen et al., 2022; Shin et al., 2021).

In implementing project-based learning to improve scientific literacy, study analysis revealed that project-based learning for early childhood has been implemented in Asia, Europe, America, and Australia. However, no reports on implementing project-based learning for early childhood have been found in Africa. In the USA., project-based learning fosters creativity and 21st-century skills, including scientific literacy, through projects such as creating simple tools or simulating scientific phenomena (Miller & Krajcik, 2019). However, findings revealed that implementing project-based learning for early childhood to support the improvement of scientific literacy has become increasingly widespread. The analysis for each country showed that Turkey, the USA, and the PRC dominated the implementation, followed by other countries supporting project-based learning for early childhood. Project-based learning for early childhood has gained significant attention in supporting the growth and development of early childhood scientific literacy abilities.

In general, project-based learning significantly contributes to improving scientific literacy in early childhood education. Project-based learning provides early childhood opportunities to develop their skills in investigating, analyzing, and explaining scientific phenomena directly, which are essential elements of scientific literacy. This approach offers conceptual understanding and trains practical skills relevant to real-life situations (PISA, 2023). Improving scientific literacy in early childhood shows various implementations through project-based learning, which divides the focus of study into four main subjects: physics, biology, technology, and astronomy. Each subject is designed to support the development of scientific skills in early childhood in a structured manner. Research indicates that project-based learning offers a more in-depth learning experience than conventional methods in improving scientific literacy in early childhood (S.-Y. Chen et al., 2022).

Various studies support the effectiveness of project-based learning in improving scientific literacy. Project-based learning at the early childhood education level has been proven to help early childhood understand scientific concepts through simple exploration and investigation activities (S.-Y. Chen et al., 2022). Early childhood is directly involved in projects like exploring a zoo to learn about various animals and then writing and illustrating those animals within the context of biological studies, focusing on living organisms (Buchholz & Pyles, 2018). In the field of physics, project-based learning emphasizes the early childhood ability to explain scientific phenomena and use experimental tools through simple projects, such as investigating shadows of objects to understand the properties of light (Fragkiadaki et al., 2024; Impedovo et al., 2017). Exploring physical phenomena through simple experiments improves early childhood curiosity and motivation to learn (Güley & Keskinçelik, 2024). In scientific literacy education in the field of astronomy, project-based learning helps children understand the scale, space, and relationships between celestial bodies, such as planets, moons, and stars, by assembling and arranging the solar system (Ampartzaki & Kalogiannakis, 2016). This interactive project improves early childhood scientific literacy ability and understanding of the universe.

Project-based learning involves assembling simple robots or utilizing everyday technological devices (Parwoto et al., 2024). These activities encourage early childhoods to understand how technology works while developing problem-solving skills. In biology, project-based learning is directed toward exploring living organisms, such as plants, animals, and simple ecosystems. Early childhood can study life cycles or interactions within the environment through projects like planting plants or observing insect behavior (García-González & Schenetti, 2022). This approach provides a concrete understanding of the relationship between living organisms and improves early childhood awareness of the importance of preserving the environment (Beasley et al., 2021).

This study demonstrates that project-based scientific literacy learning provides meaningful hands-on experiences and integrates approaches that suit early childhood developmental needs. Support from various previous studies strengthens these findings, emphasizing that each scientific literacy subject significantly contributes to developing early childhood scientific understanding. Project-based learning improves the understanding of scientific concepts and builds communication skills (Shin et al., 2021). In other learning implications, project-based approaches are applied in learning about food ingredients and food preparation, where children investigate and interpret food ingredients within scientific studies, such as food chemistry, to improve their critical and investigative thinking skills.

The use of learning media in early childhood education has grown rapidly, particularly with the emergence of new technologies that are increasingly dominating the field. Learning media today are no longer limited to conventional methods but involve technological innovations such as experimental tools, toys, AR, VR, robots, and AI. Each type of media has strengths and contributions to support the development of scientific literacy in early childhood. Experimental tools and toys are more traditional learning media but still effective. Both provide early childhood learning opportunities,



hands-on experiments, and play involvement. However, compared to new technologies, these media tend to be limited in providing a more dynamic and interactive learning experience (GarcíaGonzález & Schenetti, 2022).

On the other hand, AR and VR offer more immersive and visual learning experiences. AR allows children to interact with 3D objects that closely resemble real-world objects, helping them better understand abstract science concepts (Başaran & Bay, 2023; Gecu-Parmaksiz & Delialioğlu, 2019). Meanwhile, VR takes learning to the next level by creating full simulations, allowing children to feel like they are in the world of science (Belda-Medina & Marrahi-Gomez, 2023). Both open up opportunities for deeper, more interactive learning experiences that are harder to achieve with traditional learning methods. Robots also play a crucial role in improving early childhood scientific literacy, especially in introducing basic technology and programming concepts. Robots can be taught to perform specific tasks, such as moving objects or identifying them, helping early childhood understand the practical applications of science and technology (Parwoto et al., 2024). However, using robots requires more supervision and is often limited to certain ages or skill levels (Cherniak et al., 2019).

Meanwhile, AI, particularly chatbots like ChatGPT, offers a new dimension to learning. AI helps children communicate with technology and receive information more interactively and responsively (Su & Yang, 2024). Early childhood learn about various science concepts in a more personalized manner that suits their needs, as AI can provide tailored answers based on the questions asked. Additionally, AI introduces children to more complex scientific objects and phenomena through conversations and digital interactions. Overall, media based on AR, VR, and AI have great potential to revolutionize how early childhood learn science.

Compared to traditional learning media, such as experimental tools and toys, these technologies allow for more engaging, immersive, and interactive learning experiences (Kewalramani et al., 2021). With their ability to present more realistic and accessible experiences, these technologies allow early childhoods to understand scientific concepts more enjoyable and relevantly, in line with modern developments. Therefore, implementing these technologies in learning can significantly support the improvement of early childhood scientific literacy, paving the way for children to engage more closely with the ever-evolving world of science.

In general, previous studies have reported positive impacts from implementing project-based learning, but other studies have revealed that project-based learning has negative or no effect on learning outcomes. The failure to implement project-based learning to improve scientific literacy in early childhood is caused by several factors. One major factor is the unpreparedness of supporting resources, such as learning media that do not align with the needs and characteristics of children. The selection of inappropriate media can lead to an ineffective learning process, ultimately hindering the development of early childhood scientific literacy (Eliza et al., 2024). For instance, using play-based media requires closer supervision and control to ensure that early childhood focus remains on the learning objectives rather than just on play activities. If not properly managed, this can divert early childhood attention away from the primary goal of scientific literacy ability mastery. Implementing project-based learning that does not provide complete experimental tools or equipment has resulted in suboptimal project-based learning execution, which impacts the low development of early childhood scientific literacy (Ennes et al., 2023). Learning that uses uncontrolled toys as tools during implementation has a detrimental effect on early childhood scientific literacy abilities, as the focus tends to be more on play rather than on learning (García-González & Schenetti, 2022; Havu-Nuutinen et al., 2022).

Furthermore, implementing project-based learning requires proper design according to the characteristics of the children. Incorrect application of technology can prevent learning from affecting early childhood (Gecu-Parmaksiz & Delialioğlu, 2019). In addition, a lack of understanding about using play-based tools as part of project-based learning leads to a decline in the quality of learning. Another factor contributing to failure is the teacher's readiness to systematically plan and implement project-based learning. Project-based learning cannot be effectively applied without careful planning, resulting in suboptimal outcomes. Teachers need to prepare various resources, such as appropriate learning media, adequate time allocation, and an understanding of the developmental readiness of early childhood to engage with this approach. Considering these challenges, teachers and education practitioners must design project-based learning more carefully and systematically, ensuring that the media and methods used align with the characteristics and needs of early childhood learners.

The success of project-based learning in improving scientific literacy for early childhood heavily depends on the teacher's readiness to design and carry out projects that align with the early childhood developmental stages (Daryanes et al., 2023). Support in infrastructure and resources also plays a crucial role in the success of implementation. Studies show that developing teacher competencies is key to successfully implementing project-based learning (Anisimova, 2020; Yıldırım, 2021). Project-based learning improves their learning experience (Tsybulsky & Muchnik-Rozanov, 2021), and a supportive learning environment is essential for successfully implementing project-based learning. A well-directed and structured learning system has proven to be an important characteristic of successful project-based learning (Markula & Aksela, 2022).

Research shows that project-based learning encourages early childhoods to think critically and creatively, develop collaboration skills, and acquire social skills necessary for everyday life (Brodin & Renblad, 2020; Hjetland et al., 2020). Early childhoods actively learn through interactions and activities involving play, music, and mathematical tasks (Askarov, 2022; Joo et al., 2020). Therefore, project-based learning supports scientific literacy and strengthens other essential skills and values for the child's development. The combination of educational theory and empirical evidence indicates that project-based learning is a highly potential approach to be applied in various educational contexts, especially in building the foundation for scientific literacy in early childhood education.

The literature analysis provides a significant contribution by presenting an analysis of trends and gaps in project-based learning research for early childhood education, which is highly valuable and deserves further attention. The unique findings of this study highlight that the application of project-based learning in early childhood positively impacts the development of early childhood scientific literacy. Project-based learning has been implemented across various scientific subjects, including physics, biology, technology, and chemistry. However, challenges persist in applying project-based learning in early childhood education, particularly regarding the readiness of learning media that supports interactivity for early childhood. When using play-based media, project-based learning tends to be more effective in capturing children's attention, though there is potential for distraction if not managed properly. The uncontrolled use of play tools can negatively affect early childhood mastery of scientific literacy. Therefore, implementing technology-based learning media, such as AR, VR, and AI, offers a relevant new approach to project-based learning. Teachers' readiness to adopt project-based learning is a strategic step in overcoming these challenges. Planning lessons systematically, preparing appropriate learning media, and focusing on the scientific literacy subjects taught in early childhood are critical steps to ensure the successful implementation of project-based learning.

Conclusions and Implications

The results of this literature review study reveal that 55 articles published between 2014 and 2024 met the review criteria. These articles focus on various approaches, trends, subjects, effects, and learning media used in implementing project-based learning to improve scientific literacy ability in early childhood education. The findings highlight two primary approaches: 1) narrative and dialogue-based learning and 2) project-based learning. Project-based learning has been widely applied across 16 countries in Asia, America, Australia, and Europe. Overall, project-based learning significantly enhances early childhood scientific literacy in subjects such as physics, biology, technology, and astronomy. Integrating learning media, such as toys, experimental tools, and digital technologies, is crucial in advancing scientific literacy in early childhood education.

Based on these findings, practitioners and policymakers can support the mastery of scientific literacy in early childhood through strategic measures. One key step is the application of project-based learning, which has proven effective in developing early childhood scientific literacy. The success of project-based learning depends on careful planning, including the selection of relevant scientific topics. Additionally, appropriate resource allocation should be considered, such as using learning media that align with the characteristics of early childhood and current technological advancements. Using teaching aids, experiments, and technologies like AR, VR, and AI enriches early childhood learning experiences. Training and guidance to teachers in implementing project-based learning for early childhood is necessary to minimize potential challenges and ensure successful implementation. Well-prepared strategies, proper lesson design, and the utilization of innovative learning media are essential steps in the project-based learning process to enhance scientific literacy in early childhood. Although the potential and possibilities for implementing project-based learning are significant, with diverse support from technology-based learning media, further efforts are needed to overcome existing challenges. However, A key limitation of this study is the lack of direct input from stakeholders, such as educators and policymakers. Future research should involve in-depth interviews with these stakeholders to gain insights into the practical application of project-based learning in real-world settings, making the findings more relevant and applicable. In addition, subsequent researchers may explore the impact of integrating technology-based learning media, such as AI, in project-based learning to enhance the developing of 21st-century skills in early childhood. Research could also focus on expanding the scope to investigate the long-term impact of project-based learning.

Acknowledgements

This research was made possible through grant funding from the Research Center of the State University of Padang (Universitas Negeri Padang) No: 1512/UN35.15/LT/2024.



Declaration of Interest

The authors declare no competing interest.

References

- Adbo, K., & Vidal Carulla, C. (2020). Learning about science in preschool: Play-based activities to support children's understanding of chemistry concepts. *International Journal of Early Childhood*, 52(1), 17–35. <https://doi.org/10.1007/s13158-020-00259-3>
- Admawati, H., Jumadi, J., & Nursyahidah, F. (2018). The effect of STEM project-based learning on students' scientific attitude based on social constructivism theory. *Mathematics, Informatics, Science, and Education International Conference (MISEIC 2018)*, 270–273. <https://doi.org/10.2991/miseic-18.2018.65>
- Afriana, J., Permanasari, A., & Fitriani, A. (2016). Project based learning integrated to STEM to enhance elementary school's students scientific literacy. *Jurnal Pendidikan IPA Indonesia*, 5(2), 261–267. <https://doi.org/10.15294/jpii.v5i2.5493>
- Ahi, B. (2017). Thinking about digestive system in early childhood: A comparative study about biological knowledge. *Cogent Education*, 4(1), 1–16. <http://dx.doi.org/10.1080/2331186X.2017.1278650>
- Alan, Ü., & Erdoğan, S. (2018). Of course scientists haven't seen dinosaurs on the beach: Turkish kindergartners' developing understanding of the nature of science through explicit–reflective instruction. *Early Childhood Education Journal*, 46(6), 695–706. <https://doi.org/10.1007/s10643-018-0892-z>
- Alemneh, S., & Gebrie, G. (2024). The role of project-based learning in improving the writing ability and sub-writing abilities of 10th grade Amharic speaking students. *Social Sciences & Humanities Open*, 9(2), 220–230. <https://doi.org/10.2139/ssrn.4596147>
- Allen, M., Harper, L., & Clark, Z. (2021). Preschoolers' concepts of digestive physiology and their links with body mass index. *Research in Science Education*, 51(6), 1795–1816. <https://doi.org/10.1007/s11165-019-9859-3>
- Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *Sage Open*, 10(3). <https://doi.org/10.1177/2158244020938702>
- Alzahrani, N. M. (2020). Augmented reality: A systematic review of its benefits and challenges in e-learning contexts. *Applied Sciences*, 10(16). <https://doi.org/10.3390/app10165660>
- Ampartzaki, M., & Kalogiannakis, M. (2016). Astronomy in early childhood education: A concept-based approach. *Early Childhood Education Journal*, 44 (2), 169–179. <https://doi.org/10.1007/s10643-015-0706-5>
- Anisimova, E. (2020). Digital literacy of future preschool teachers. *Journal of Social Studies Education Research*, 11(1), 230–253.
- Aravantis, S., Lavidas, K., Voulgari, I., Papadakis, S., Karalis, T., & Komis, V. (2024). Educational approaches with AI in primary school settings: A systematic review of the literature available in scopus. *Education Sciences*, 14(7), 744.
- Aristeidou, M., & Herodotou, C. (2020). Online citizen science: A systematic review of effects on learning and scientific literacy. *Citizen Science: Theory and Practice*, 5(1), 1–12. <https://doi.org/10.5334/cstp.224>
- Askarov, A. (2022). Creative Thinking in preschool social psychological aspects of development. *Science and Innovation*, 1(8), 87–91. <https://doi.org/10.37547/supsci-ojss-03-01-02>
- Başaran, M., & Bay, E. (2023). The effect of project-based STEAM activities on the social and cognitive skills of preschool children. *Early Child Development and Care*, 193(5), 679–697.
- Bauer, J.-R., & Booth, A. E. (2019). Exploring potential cognitive foundations of scientific literacy in preschoolers: Causal reasoning and executive function. *Early Childhood Research Quarterly*, 46, 275–284. <https://doi.org/10.1016/j.ecresq.2018.09.007>
- Beasley, K., Lee-Hammond, L., & Hesterman, S. (2021). A framework for supporting the development of botanical literacies in early childhood education. *International Journal of Early Childhood*, 53(2), 119–137. <https://doi.org/10.1007/s13158-021-00291-x>
- Belda-Medina, J., & Marrahi-Gomez, V. (2023). The impact of augmented reality (AR) on vocabulary acquisition and student motivation. *Electronics*, 12(3), 749.
- Booth, A. E., Shavlik, M., & Haden, C. A. (2020). Parents' causal talk: Links to children's causal stance and emerging scientific literacy. *Developmental Psychology*, 56(11), 20–55. <https://doi.org/10.1037/dev0001108.supp>
- Booth, A. E., Shavlik, M., & Haden, C. A. (2022). Exploring the foundations of early scientific literacy: Children's causal stance. *Developmental Psychology*, 58(12), 23–32. <https://psycnet.apa.org/doi/10.1037/dev0001433>
- Bracken, B. A., & Theodore, L. A. (2020). Creating the optimal preschool testing situation. In *Psychoeducational assessment of preschool children* 12(2), 55–75. Routledge. <https://doi.org/10.4324/9780429054099-3>
- Brighouse, H. (2024). Education. In *The Routledge Companion to Social and Political Philosophy* (pp. 751–762). Routledge.
- Brodin, J., & Renblad, K. (2020). Improvement of preschool children's speech and language skills. *Early Child Development and Care*, 190(14), 2205–2213. <https://doi.org/10.1002/trtr.1678>
- Buchholz, B. A., & Pyles, D. G. (2018). Scientific literacy in the wild: Using multimodal texts in and out of school. *The Reading Teacher*, 72(1), 61–70. <https://doi.org/10.1002/trtr.1678>
- Can, B., Yildiz-Demirtas, V., & Altun, E. (2017). The effect of projectbased science education programme on scientific process skills and conceptions of kindergarten students. *Journal of Baltic Science Education*, 16(3), 395–413. <https://doi.org/10.33225/jbse/17.16.395>
- Cascarosa, E., Mazas, B., & Mateo, E. (2022). Are early-years-children able to use magnifying glasses and dichotomous keys to observe, compare, classify and identify small animals? *Journal of Biological Education*, 56(2), 222–241. <https://doi.org/10.1080/00219266.2020.1776753>
- Chen, R. W., & Chan, K. K. (2019). Using augmented reality flashcards to learn vocabulary in early childhood education. *Journal of Educational Computing Research*, 57(7), 1812–1831. <https://doi.org/10.1177/0735633119854028>

- Chen, S.-Y., Lai, C.-F., Lai, Y.-H., & Su, Y.-S. (2022). Effect of project-based learning on development of students' creative thinking. *The International Journal of Electrical Engineering & Education*, 59(3), 232–250. <https://doi.org/10.1177/0020720919846808>
- Cherniak, S., Lee, K., Cho, E., & Jung, S. E. (2019). Child-identified problems and their robotic solutions. *Journal of Early Childhood Research*, 17(4), 347–360. <https://doi.org/10.1177/1476718x19860557>
- Connor, C. M., Dombek, J., Crowe, E. C., Spencer, M., Tighe, E. L., Coffinger, S., Zargar, E., Wood, T., & Petscher, Y. (2017). Acquiring science and social studies knowledge in kindergarten through fourth grade: Conceptualization, design, implementation, and efficacy testing of content-area literacy instruction (CALI). *Journal of Educational Psychology*, 109(3), 301. <https://doi.org/10.1037/edu0000128>
- Crespi, P., García-Ramos, J. M., & Queiruga-Dios, M. (2022). Project-based learning (PBL) and its impact on the development of interpersonal competences in higher education. *Journal of New Approaches in Educational Research*, 11(2), 259–276. <https://doi.org/10.7821/naer.2022.7.993>
- Dale Tunnicliffe, S., & Gkouskou, E. (2020). Science in action in spontaneous preschool play—an essential foundation for future understanding. *Early Child Development and Care*, 190(1), 54–63. <https://doi.org/10.1080/03004430.2019.1653552>
- Daryanes, F., Darmadi, D., Fikri, K., Sayuti, I., Rusandi, M. A., & Situmorang, D. D. B. (2023). The development of articulate storyline interactive learning media based on case methods to train student's problem-solving ability. *Heliyon*, 9(4). <https://doi.org/10.1080/03004430.2019.1653552>
- de Brito Miranda, A. C., Jófili, Z., & dos Anjos Carneiro-Leão, A. M. (2017). Ecological literacy—preparing children for the twenty-first century. *Early Child Development and Care*, 187(2), 192–205. <https://doi.org/10.4324/9780429442698-3>
- Dhanil, M., & Mufit, F. (2024). How virtual reality impacts science learning? A Meta-analysis. *International Association of Online Engineering*, 18(22), 77–96. <https://doi.org/10.3991/ijim.v18i22.49989>
- Doshi, A., Weinert, S., & Attig, M. (2024). Self-regulatory abilities as predictors of scientific literacy among children in preschool and primary school years. *Learning and Individual Differences*, 114, 102515. <https://doi.org/10.1016/j.lindif.2024.102515>
- Eliza, D., Mulyeni, T., Budayawan, K., Hartati, S., Khairiah, F., & Permana, A. I. (2022). Development of Integrated Local Wisdom Digital Technology Science Stories for Early Childhood (Pengembangan Teknologi Digital Cerita Sains Terintegrasi Kearifan lokal untuk Anak Usia Dini). *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, 6(6), 7069–7077. <https://doi.org/https://doi.org/10.31004/obsesi.v6i6.3640>
- Eliza, D., Mulyeni, T., Budayawan, K., Hartati, S., & Khairiah, F. (2024). Creation of cultural local wisdom-based picture-science stories application for the introduction of scientific literacy for early childhood. *JOIV: International Journal on Informatics Visualization*, 8(1), 417–424. <http://dx.doi.org/10.62527/joiv.8.1.2234>
- Ennes, M. E., Jones, M. G., Childers, G. M., Cayton, E. M., & Chesnutt, K. M. (2023). Children and parents' perceptions of access to science tools at home and their role in science self-efficacy. *Research in Science Education*, 53(4), 671–687. <https://doi.org/10.1007/s11165-022-10077-3>
- Fragkiadaki, G., Fleer, M., & Rai, P. (2023). Science concept formation during infancy, toddlerhood, and early childhood: Developing a scientific motive over time. *Research in Science Education*, 53(2), 275–294. <https://doi.org/10.1007/s11165-022-10053-x>
- Fragkiadaki, G., Frangedaki, E.-M., Zachariadi, I., & Christidou, V. (2024). Scientific toys in early childhood settings: teaching and learning about light and shadows. *Research in Science Education*, 1–29. <https://doi.org/10.1007/s11165-024-10223-z>
- García-González, E., & Schenetti, M. (2022). Education in nature and learning science in early childhood: A fertile and sustainable symbiosis. *Journal of Outdoor and Environmental Education*, 25(3), 363–377. <https://doi.org/10.1007/s42322-022-00110-4>
- Gecu-Parmaksiz, Z., & Delialioglu, O. (2019). Augmented reality-based virtual manipulatives versus physical manipulatives for teaching geometric shapes to preschool children. *British Journal of Educational Technology*, 50(6), 3376–3390.
- González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of education 4.0 in 21st century skills frameworks: Systematic review. *sustainability*, 14(3), <https://doi.org/10.3390/su14031493>
- González-Salamanca, J. C., Agudelo, O. L., & Salinas, J. (2020). Key competences, education for sustainable development and strategies for the development of 21st century skills. A systematic literature review. *Sustainability*, 12(24). <https://doi.org/10.3390/su122410366>
- Gray, A. M., Sirinides, P. M., Fink, R. E., & Bowden, A. B. (2022). Integrating literacy and science instruction in kindergarten: Results from the efficacy Study of Zoology One. *Journal of Research on Educational Effectiveness*, 15(1), 1–27. <https://doi.org/10.1080/19345747.2021.1938313>
- Greca Dufranc, I. M., García Terceño, E., Fridberg, M., Cronquist, B., & Redfors, A. (2020). Robotics and early-years STEM education: The botSTEM framework and activities. *European Journal of STEM Education*, 1, 1–13. <https://doi.org/10.20897/ejsteme/7948>
- Güley, B., & Keskinkılıç, A. (2024). The effect of project approach-based science education program on problem-solving skills of preschool children. *Humanities and Social Sciences Communications*, 11(1), 1–10. <https://doi.org/10.1057/s41599-024-03444-0>
- Guo, Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, 102, 101586. <https://doi.org/10.1016/j.ijer.2020.101586>
- Havu-Nuutinen, S., Kewalramani, S., Veresov, N., Pöntinen, S., & Kontkanen, S. (2022). Understanding early childhood science education: Comparative analysis of Australian and Finnish curricula. *Research in Science Education*, 1–16. <https://doi.org/10.1007/s11165-020-09980-4>
- Hawari, A. D. M., & Noor, A. I. M. (2020). Project based learning pedagogical design in STEAM art education. *Asian Journal of University Education*, 16(3), 102–111. <https://doi.org/10.24191/ajue.v16i3.11072>
- Hjetland, H. N., Brinchmann, E. I., Scherer, R., Hulme, C., & Melby-Lervåg, M. (2020). Preschool pathways to reading comprehension: A systematic meta-analytic review. *Educational Research Review*, 30, 100323. <https://doi.org/10.1016/j.edurev.2020.100323>
- Hsin, C.-T., & Wu, H.-K. (2023). Implementing a project-based learning module in urban and indigenous areas to promote young children's scientific practices. *Research in Science Education*, 53(1), 37–57. <https://doi.org/10.1007/s11165-022-10043-z>
- Hu, H. (2022). Rethinking nature journaling in the Kindergarten Program action research in learning and teaching. *Journal of Outdoor and Environmental Education*, 25(2), 159–179. <https://doi.org/10.1007/s42322-022-00095-0>



- Impedovo, M. A., Delserieys-Pedregosa, A., Jégou, C., & Ravanis, K. (2017). Shadow formation at preschool from a socio-materiality perspective. *Research in Science Education*, 47, 579–601. <https://doi.org/10.1007/s11165-016-9518-x>
- Joo, Y. S., Magnuson, K., Duncan, G. J., Schindler, H. S., Yoshikawa, H., & Ziol-Guest, K. M. (2020). What works in early childhood education programs?: A meta-analysis of preschool enhancement programs. *Early Education and Development*, 31(1), 1–26. <https://doi.org/10.1080/10409289.2019.1624146>
- Junge, K., Schmerse, D., Lankes, E.-M., Carstensen, C. H., & Steffensky, M. (2021). How the home learning environment contributes to children's early science knowledge—associations with parental characteristics and science-related activities. *Early Childhood Research Quarterly*, 56, 294–305. <https://doi.org/10.1016/j.ecresq.2021.04.004>
- Kaehler, J., Hahn, I., & Koeller, O. (2020). The development of early scientific literacy gaps in kindergarten children. *International Journal of Science Education*, 42(12), 1988–2007. <https://doi.org/10.1080/09500693.2020.1808908>
- Kewalramani, S., Kidman, G., & Palaiologou, I. (2021). Using artificial intelligence (AI)-interfaced robotic toys in early childhood settings: A case for children's inquiry literacy. *European Early Childhood Education Research Journal*, 29(5), 652–668.
- Koerber, S., & Osterhaus, C. (2019). Individual differences in early scientific thinking: Assessment, cognitive influences, and their relevance for science learning. *Journal of Cognition and Development*, 20(4), 510–533. <https://doi.org/10.1080/15248372.2019.1620232>
- Koerber, S., & Osterhaus, C. (2021). Science competencies in kindergarten: a prospective study in the last year of kindergarten. *Unterrichtswissenschaft*, 49(5914), 1–20. <https://doi.org/10.1007/s42010-020-00093-5>
- Kokkalia, G. K., & Drigas, A. S. (2016). Mobile learning for special preschool education. *International Journal of Interactive Mobile Technologies*, 10(1).
- Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, 19(3), 267–277.
- Kumar, S. C., Haber, A. S., & Corriveau, K. H. (2024). Exploring how teachers' scientific questions differ by child gender in a preschool classroom. *Mind, Brain, and Education*, 18(1), 57–61. <https://doi.org/10.1111/mbe.12400>
- Kusuma, G. A., Wirawan, I., & Arthana, I. (2018). *Virtual reality for learning fish types in kindergarten*.
- Larimore, R. A. (2020). Preschool science education: A vision for the future. *Early Childhood Education Journal*, 48(6), 703–714. <https://doi.org/10.1007/s10643-020-01033-9>
- Lazaroff, E., & Vlach, H. A. (2022). Children's science vocabulary uniquely predicts individual differences in science knowledge. *Journal of Experimental Child Psychology*, 221, 105427. <https://doi.org/10.1016/j.jecp.2022.105427>
- Lorusso, M. L., Travellini, S., Giorgetti, M., Negrini, P., Reni, G., & Biffi, E. (2020). Semi-immersive virtual reality as a tool to improve cognitive and social abilities in preschool children. *Applied Sciences*, 10(8), 2948.
- Markula, A., & Aksela, M. (2022). The key characteristics of project-based learning: How teachers implement projects in K-12 science education. *Disciplinary and Interdisciplinary Science Education Research*, 4(1), 2. <https://doi.org/10.1186/s43031-021-00042-x>
- Maros, M., Korenkova, M., Fila, M., Levicky, M., & Schoberova, M. (2023). Project-based learning and its effectiveness: evidence from Slovakia. *Interactive Learning Environments*, 31(7), 4147–4155. <https://doi.org/10.18421/tem114-07>
- McNerney, K., Carritt, D., Dealey, H., & Ladbury, G. (2020). Using a scientific enquiry framework, focusing on questions, to promote enquiry skills in early childhood. *Early Child Development and Care*, 190(1), 30–42. <https://doi.org/10.1080/03004430.2019.1653549>
- Miller, E. C., & Krajcik, J. S. (2019). Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research*, 1(1), 7. <https://doi.org/10.1186/s43031-019-0009-6>
- Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Group PRISMA. 2009. preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *Annals of Internal Medicine*, 151(4), 264–269. <https://doi.org/10.7717/peerj.15039/fig-1>
- Mursid, R., Saragih, A. H., & Hartono, R. (2022). The effect of the blended project-based learning model and creative thinking ability on engineering students' learning outcomes. *International Journal of Education in Mathematics, Science and Technology*, 10(1), 218–235. <https://doi.org/10.46328/ijemst.2244>
- Nevo, E., & Vaknin-Nusbaum, V. (2018). Joint reading of informational science text versus narrative stories: How does each affect language and literacy abilities among kindergarteners? *Reading Psychology*, 39(8), 787–819. <https://doi.org/10.1080/02702711.2018.1547343>
- Oranç, C., & Küntay, A. C. (2019). Learning from the real and the virtual worlds: Educational use of augmented reality in early childhood. *International Journal of Child-Computer Interaction*, 21, 104–111. <https://doi.org/10.1016/j.ijcci.2019.06.002>
- Paños, E., & Ruiz-Gallardo, J. (2021). Attitude toward informal science in the early years and development of Leisure Time in Science (LeTIS), a pictographic scale. *Journal of Research in Science Teaching*, 58(5), 689–720. <https://doi.org/10.1002/tea.21675>
- Parwoto, P., Ilyas, S. N., Bachtiar, M. Y., & Marzuki, K. (2024). Fostering creativity in kindergarten: The impact of collaborative project-based learning. *South African Journal of Childhood Education*, 14(1), 1462. <https://doi.org/10.4102/sajce.v14i1.1462>
- Passig, D., Tzuriel, D., & Eshel-Kedmi, G. (2016). Improving children's cognitive modifiability by dynamic assessment in 3D Immersive Virtual Reality environments. *Computers & Education*, 95, 296–308.
- Pereira, S., Rodrigues, M. J., & Vieira, R. M. (2020). Scientific literacy in the early years—practical work as a teaching and learning strategy. *Early Child Development and Care*, 190(1), 64–78. <https://doi.org/10.1080/03004430.2019.1653553>
- PISA, O. (2023). *PISA 2022: Assessment and analytical framework*. PISA, OECD Publishing Paris.
- Saad, A., & Zainudin, S. (2022). A review of project-based learning (PBL) and computational thinking (CT) in teaching and learning. *Learning and Motivation*, 78, 101802. <https://doi.org/10.1016/j.lmot.2022.101802>
- Saçkes, M., Trundle, K. C., & Shaheen, M. (2020). The effect of balanced learning curriculum on young children's learning of science. *Early Childhood Education Journal*, 48, 305–312. <https://doi.org/10.1007/s10643-019-00985-x>
- Shin, N., Bowers, J., Krajcik, J., & Damelin, D. (2021). Promoting computational thinking through project-based learning. *Disciplinary and Interdisciplinary Science Education Research*, 3, 1–15. <https://doi.org/10.1186/s43031-021-00033-y>
- Su, J., & Yang, W. (2024). Artificial Intelligence (AI) literacy in early childhood education: An intervention study in Hong Kong. *Interactive Learning Environments*, 32(9), 5494–5508.

- Tsybulsky, D., & Muchnik-Rozanov, Y. (2021). Project-based learning in science-teacher pedagogical practicum: the role of emotional experiences in building preservice teachers' competencies. *Disciplinary and Interdisciplinary Science Education Research*, 3(1), 9.
- Valladares, L. (2021). Scientific literacy and social transformation: Critical perspectives about science participation and emancipation. *Science & Education*, 30(3), 557–587. <https://doi.org/10.1007/s11191-021-00205-2>
- Weng, C., Otanga, S., Christianto, S. M., & Chu, R. J. C. (2020). Enhancing students' biology learning by using augmented reality as a learning supplement. *Journal of Educational Computing Research*, 58(4), 747–770. <https://doi.org/10.1177/0735633119884213>
- Wight, R. A., Kloos, H., Maltbie, C. V., & Carr, V. W. (2016). Can playscapes promote early childhood inquiry towards environmentally responsible behaviors? An exploratory study. *Environmental Education Research*, 22(4), 518–537. <http://dx.doi.org/10.1080/13504622.2015.1015495>
- Wright, T. S., & Gotwals, A. W. (2017). Supporting kindergartners' science talk in the context of an integrated science and disciplinary literacy curriculum. *The Elementary School Journal*, 117(3), 513–537. <https://doi.org/10.1086/690273>
- Yilmaz, R. M. (2016). Educational magic toys developed with augmented reality technology for early childhood education. *Computers in Human Behavior*, 54, 240–248. <https://doi.org/10.1016/j.chb.2015.07.040>
- Yıldırım, B. (2021). Preschool STEM activities: Preschool teachers' preparation and views. *Early Childhood Education Journal*, 49(2), 149–162.
- Zhao, Y., & Wang, L. (2022). A case study of student development across project-based learning units in middle school chemistry. *Disciplinary and Interdisciplinary Science Education Research*, 4(1), 5. <https://doi.org/10.1186/s43031-021-00045-8>
- Zhou, W., & Yang, W. (2024). Story-based STEM design challenges in early childhood education: child engagement and pedagogical strategies. *Early Childhood Education Journal*, 1–16. <https://doi.org/10.1007/s10643-024-01733-6>

Received: December 25, 2024

Revised: January 14, 2024

Accepted: January 25, 2025

Cite as: Eliza, D., Mulyeni, T., Yulsyofriend, Y., Mahyuddin, N., Erita, Y., & Dhanil, M. (2025). Implementation of project-based learning in improving scientific literacy in early childhood education: Systematic literature review. *Journal of Baltic Science Education*, 24(1), 71–91. <https://doi.org/10.33225/jbse/25.24.71>



Delfi Eliza
(Corresponding author)

PhD, State University of Padang (Universitas Negeri Padang), Prof. Dr. Hamka Street, Air Tawar Padang, West Sumatra, Indonesia.
E-mail: deliza.zarni@gmail.com
ORCID: <https://orcid.org/0000-0003-0310-3083>

Trisna Mulyeni

PhD, Lecturer, Jakarta State University (Universitas Negeri Jakarta), Jl. R.Mangun Muka Raya No.11, RT.11/RW.14, Rawamangun, Kec. Pulo Gadung, Kota Jakarta Timur, Daerah Khusus Ibukota Jakarta 13220, Indonesia.
E-mail: trisna_mulyeni@unj.ac.id
ORCID: <https://orcid.org/0000-0002-1666-1917>

Yulsyofriend

State University of Padang (Universitas Negeri Padang), Prof. Dr. Hamka Street, Air Tawar Padang, West Sumatra, Indonesia.
E-mail: yulsyofriend@fip.unp.ac.id
ORCID: <https://orcid.org/0009-0007-6743-2173>

Nenny Mahyuddin

State University of Padang (Universitas Negeri Padang), Prof. Dr. Hamka Street, Air Tawar Padang, West Sumatra, Indonesia.
E-mail: nennymahyuddin@fip.unp.ac.id
ORCID: <https://orcid.org/0000-0001-9786-8583>

Yeni Erita

State University of Padang (Universitas Negeri Padang), Prof. Dr. Hamka Street, Air Tawar Padang, West Sumatra, Indonesia.
E-mail: yenierita@fip.unp.ac.id
ORCID: <https://orcid.org/0000-0001-5957-0399>

Muhammad Dhanil

State University of Padang (Universitas Negeri Padang), Prof. Dr. Hamka Street, Air Tawar Padang, West Sumatra, Indonesia
E-mail: muhammaddhanil22@gmail.com
ORCID: <https://orcid.org/0000-0001-8934-4149>

