Volume 2 Issue 5 (October,2025)
Jurnal of Pedagogi : Jurnal Pendidikan
ISSN: : 3046-9554 (Online)

The Impact of Project-Based Learning on Students' Science Literacy and Environmental Awareness: A Comprehensive Review

Bambang Kulup Karnoto[1], Dwiyanto[2], Muhammad Arsyad[3]
Universitas Negeri Jakarta, Indonesia[1], Politeknik Penerbangan Surabaya, Indonesia[2], Universitas Halu Oleo, Indonesia[3]
DOI: https://doi.org/10.62872/80h4ry59

Abstract

Project-Based Learning (PjBL) has emerged as a transformative pedagogical approach that significantly enhances students' science literacy and environmental awareness across various educational levels. This comprehensive review synthesizes evidence from 20 empirical studies and systematic reviews conducted primarily in Indonesia between 2020 and 2025, examining the effectiveness of PjBL in developing scientific competencies and environmental consciousness. The findings consistently demonstrate that PjBL significantly improves students' science literacy scores, critical thinking abilities, problem-solving skills, and conceptual understanding compared to conventional teaching methods. Furthermore, PjBL effectively cultivates environmental awareness, pro-environmental attitudes, and action-taking behaviors among students through engagement with authentic environmental issues. The review identifies key success factors including active student involvement, integration of higher-order thinking skills, real-world problem contextualization, collaborative learning environments, and technology integration. This study reveals that PjBL effectiveness is enhanced when integrated with STEM approaches, digital storytelling, multiliteracy pedagogies, and character education. The evidence supports PjBL as a highly effective instructional model for fostering 21st-century competencies, scientific literacy, and environmental stewardship in contemporary education systems.
Keywords: Project-Based Learning, Science Literacy, Environmental Awareness, Environmental Literacy, STEM Education, Pedagogy

Corresponding author :
Email Address : kulupkarnoto@gmail.com
Received Agustus 14, 2025, Accepted October 20, 2025, Published October 23, 2025

Introduction

The rapidly evolving challenges of the 21st century demand fundamental transformations in educational approaches to prepare students with competencies that extend beyond traditional content knowledge. Contemporary education must cultivate scientifically literate citizens capable of understanding complex scientific concepts, critically evaluating evidence, solving real-world problems, and making informed decisions about pressing issues including environmental sustainability (Hudha et al., 2023). Science literacy represents not merely the acquisition of scientific facts but encompasses the ability to engage with science-related issues, apply scientific knowledge to authentic contexts, and participate meaningfully in societal discourse about science and technology (Karmana, 2024).

Simultaneously, the escalating environmental crises confronting humanity including climate change, biodiversity loss, pollution, and resource depletion necessitate urgent development of environmental awareness and literacy among younger generations (Khondokar, 2025). Environmental awareness encompasses understanding environmental problems, recognizing human impacts on

DOI: https://doi.org/10.62872/80h4ry59
ecosystems, developing pro-environmental attitudes, and engaging in environmentally responsible behaviors (Suryawati et al., 2020). Educational systems bear critical responsibility for cultivating environmental consciousness that translates into informed action and sustainable lifestyles among students who will inherit and shape the future of our planet.

Traditional pedagogical approaches characterized by teacher-centered instruction, passive learning, and disconnection from real-world contexts have proven inadequate for developing the multidimensional competencies required in contemporary society (Melindayani, 2022). Conventional science teaching often emphasizes memorization of facts and procedures rather than deep conceptual understanding, critical thinking, or application to authentic problems (Nuraini & Waluyo, 2021). Such approaches fail to engage students' intrinsic motivation, limit opportunities for meaningful learning, and do not adequately prepare students for the complex challenges they will face as citizens and professionals.

Project-Based Learning has emerged as a promising alternative pedagogical model that addresses these limitations by situating learning within authentic, meaningful contexts that require students to actively construct knowledge through extended inquiry and problem-solving (Fauziah et al., 2023). PjBL engages students in investigating complex questions or problems over extended time periods, resulting in the creation of authentic products or presentations that demonstrate their learning (Tanta, 2024). This approach fundamentally transforms the role of students from passive recipients of information to active constructors of knowledge, requiring them to collaborate, think critically, solve problems, and communicate effectively.

The theoretical foundations of PjBL draw from constructivist learning theories, which posit that knowledge is actively constructed by learners through interaction with their environment and social context rather than passively transmitted from teachers to students (Pantiwati, 2021). PjBL operationalizes constructivist principles by creating learning environments where students engage with authentic problems, collaborate with peers, access multiple information sources, and construct understanding through guided inquiry and reflection (Munawar et al., 2023). This alignment with contemporary learning theory provides strong theoretical justification for PjBL as an effective instructional approach.

In the context of science education, PjBL offers unique advantages for developing science literacy by engaging students in authentic scientific practices including questioning, investigating, analyzing data, constructing explanations, and communicating findings (Kurniasari et al., 2023). Rather than learning about science as an abstract body of facts, students engage in doing science by conducting investigations, collecting and interpreting data, and drawing evidence-based conclusions (Hudha et al., 2023). This experiential engagement with scientific practices develops deeper understanding of both scientific content and the nature of scientific inquiry itself.

For environmental education, PjBL provides powerful opportunities to connect students with local environmental issues, develop systems thinking about human-environment interactions, and cultivate sense of agency for environmental action (Pertiwi et al., 2024). Projects focused on authentic environmental problems in students' communities make abstract environmental concepts tangible and relevant, while also developing students' capacity and motivation to contribute to environmental solutions (Agustira et al., 2025). This connection between learning and local context appears particularly important for translating environmental knowledge into awareness and action.

Despite the theoretical promise and growing adoption of PjBL in educational practice, systematic synthesis of empirical evidence regarding its effectiveness for science literacy and environmental awareness development remains important for informing educational policy and practice. While individual studies have demonstrated positive outcomes, comprehensive review of the accumulated evidence base can identify patterns, clarify mechanisms of effectiveness, and reveal conditions that optimize PjBL implementation (Karmana, 2024). Such synthesis is particularly valuable for educational practitioners seeking evidence-based guidance for instructional design and implementation.

Therefore, this comprehensive review examines empirical evidence regarding the impact of Project-Based Learning on students' science literacy and environmental awareness across various educational levels and contexts. By synthesizing findings from multiple studies, this review aims to clarify the effectiveness of PjBL, identify key factors contributing to successful implementation, and provide recommendations for educational practice and future research. The specific objectives include examining PjBL effects on science literacy dimensions, investigating PjBL impacts on environmental

DOI: https://doi.org/10.62872/80h4ry59

awareness and attitudes, identifying pedagogical features that enhance PjBL effectiveness, and analyzing contextual factors influencing implementation success.

Methodology

This comprehensive review employed a systematic approach to identify, analyze, and synthesize empirical research on Project-Based Learning and its effects on science literacy and environmental awareness. The review process followed established protocols for literature synthesis to ensure rigor, transparency, and comprehensiveness in evidence gathering and analysis.

The literature search encompassed peer-reviewed journal articles published between 2020 and 2025, a timeframe selected to capture contemporary PjBL research reflecting recent developments in both pedagogical practice and educational contexts. This period proved particularly relevant as it includes research conducted during and after the COVID-19 pandemic, which significantly influenced educational practices and accelerated adoption of innovative pedagogical approaches. The search prioritized studies conducted in Indonesian contexts while remaining open to comparative international perspectives.

Inclusion criteria specified that studies must focus explicitly on Project-Based Learning as the primary instructional intervention, measure science literacy or environmental awareness as key outcome variables, employ empirical research designs including experimental, quasi-experimental, or systematic review methodologies, and be published in peer-reviewed academic journals. Studies were excluded if they examined project-based approaches without clear alignment to established PjBL principles, focused solely on achievement outcomes without addressing literacy or awareness dimensions, lacked empirical data or rigorous methodology, or were published in non-peer-reviewed venues.

The final corpus comprised 20 studies including experimental and quasi-experimental investigations of PjBL implementation across elementary, secondary, and tertiary education levels, as well as systematic literature reviews synthesizing multiple empirical studies. This diverse evidence base enabled analysis of PjBL effectiveness across different educational contexts, student populations, and implementation approaches. The studies represented various Indonesian educational settings from urban to rural contexts and from public to private institutions, enhancing generalizability of findings.

Data extraction from included studies focused on multiple dimensions including study characteristics such as educational level, sample size, and research design; PjBL implementation features including duration, project topics, integration with other approaches, and technological tools; outcome measures including instruments used to assess science literacy and environmental awareness; results including effect sizes, statistical significance, and practical significance indicators; and contextual factors including teacher preparation, student characteristics, and implementation challenges.

Thematic synthesis methodology guided the analysis process, involving initial coding of key concepts and findings from individual studies, grouping of related codes into descriptive themes that characterized patterns across studies, and development of analytical themes that generated new interpretative insights beyond individual study findings. This iterative process enabled both aggregation of consistent findings and identification of nuances and variations across different contexts and implementations.

Quality assessment of included studies considered methodological rigor including appropriateness of research design for addressing research questions, validity and reliability of measurement instruments, adequacy of sample sizes and sampling procedures, appropriate use of statistical analyses, and acknowledgment of limitations. This critical appraisal ensured that conclusions drawn from the synthesis were grounded in methodologically sound research and appropriately qualified based on evidence strength.

The synthesis process paid particular attention to distinguishing between science literacy and environmental awareness as distinct but related constructs, identifying specific PjBL features associated with positive outcomes for each, and examining potential moderating factors that influenced effectiveness. This nuanced analysis provides more refined understanding of how and under what conditions PjBL contributes to these important educational outcomes.

DOI: https://doi.org/10.62872/80h4ry59

Results and Discussion

Impact of Project-Based Learning on Science Literacy

Impact of Project-Based Learning on Environmental Awareness and Literacy

Table 1. Effects of Project-Based Learning on Science Literacy Across Educational Levels

Educational Level	**Study Design**	**Sample Context**	**Key Findings**	**Effect Indicators**	**Sources**
Elementary School	Quasi-experimental, pretest-posttest	Grade 5 students, SD Telkom Makassar	PjBL significantly improved science literacy compared to conventional teaching	Higher posttest scores, significant t-test results	Melindayani (2022)
Elementary School	Development research	Elementary school students	PjBL integrated with science process skills effectively enhanced science literacy	High N-Gain scores, improved HOTS	Nuraini & Waluyo (2021); Maslihatin (2024)
Junior High School	Quasi-experimental	Junior high school students	PjBL implementation significantly improved science literacy across dimensions	Statistically significant improvements in knowledge, competence, and context	Fauziah et al. (2023)
Senior High School	Quasi-experimental	10th-grade students, MA Al Manshuriyah	PjBL with digital storytelling significantly enhanced science literacy	Higher mean scores, improved communication and interpretation skills	Munawar et al. (2023)
Senior High School	Quasi-experimental	High school students	STEM-based blended PjBL effectively improved science literacy	Significant improvements in scientific reasoning and problem-solving	Kurniasari et al. (2023)

DOI: https://doi.org/10.62872/80h4ry59

University	Quasi-experimental	Biology education students, Cenderawasih University	Context-based PjBL significantly increased science literacy compared to conventional methods	Statistical significance ($p < 0.05$), higher mean scores	Tanta (2024)
Multiple Levels	Systematic literature review	20 studies across educational levels	PjBL consistently improved science literacy, critical thinking, and learning outcomes	Consistent positive effects across reviewed studies	Karmana (2024); Hudha et al. (2023)

Table 1 synthesizes empirical evidence demonstrating that Project-Based Learning consistently and significantly enhances science literacy across all educational levels from elementary school through university. The evidence reveals a robust pattern of positive effects that transcend specific contexts, student populations, and implementation variations, suggesting that PjBL represents a genuinely effective pedagogical approach for science literacy development rather than merely producing isolated positive results under specific conditions (Karmana, 2024; Hudha et al., 2023).

At the elementary level, research demonstrates that PjBL significantly improves young students' science literacy compared to conventional instruction methods. A quasi-experimental study with fifth-grade students at SD Telkom Makassar found that students who experienced PjBL achieved significantly higher science literacy scores on posttests compared to control group students receiving conventional instruction, with statistical analyses confirming the significance of these differences (Melindayani, 2022). The effectiveness at this early educational stage is particularly noteworthy as it suggests PjBL can successfully engage young learners in authentic scientific practices and develop foundational science literacy competencies.

The evidence demonstrates that Project-Based Learning exerts significant positive effects on multiple dimensions of science literacy including conceptual understanding, scientific reasoning, critical thinking, problem-solving abilities, and communication skills. Students participating in PjBL consistently demonstrate superior performance on science literacy assessments compared to peers receiving conventional instruction, with effect sizes indicating educationally meaningful differences (Melindayani, 2022; Fauziah et al., 2023; Tanta, 2024). These improvements manifest across various measurement approaches including standardized science literacy instruments, teacher-developed assessments, and performance-based evaluations.

The mechanisms through which PjBL enhances science literacy involve multiple interconnected processes. First, PjBL situates learning within authentic contexts that require students to apply scientific concepts to real-world problems, facilitating deeper conceptual understanding and ability to transfer knowledge to novel situations (Munawar et al., 2023). This contextualization makes abstract scientific principles concrete and meaningful, enhancing both comprehension and retention. Students engaging with tangible problems develop more robust and flexible understanding compared to learning decontextualized facts and procedures.

DOI: https://doi.org/10.62872/80h4ry59

Second, PjBL necessitates active engagement in scientific practices including questioning, investigating, data collection and analysis, evidence-based reasoning, and communication of findings (Hudha et al., 2023). Through these authentic practices, students develop both understanding of scientific content and appreciation for the nature of scientific inquiry itself. They learn not only what scientists know but how scientists generate knowledge, cultivating epistemic understanding that characterizes true science literacy (Karmana, 2024).

Third, the collaborative nature of PjBL projects creates opportunities for socially mediated learning where students co-construct understanding through discussion, argumentation, and negotiation of meaning (Nuraini & Waluyo, 2021). These social interactions support development of communication skills and ability to articulate scientific reasoning, while also exposing students to diverse perspectives and approaches to problem-solving. The dialogic processes inherent in collaborative project work enhance both individual and collective understanding.

Fourth, PjBL projects typically extend over significant time periods, allowing for iterative cycles of investigation, reflection, revision, and refinement that deepen understanding (Maslihatin, 2024). This extended engagement contrasts sharply with the superficial coverage characteristic of conventional instruction, enabling students to develop sophisticated understanding of complex phenomena. The opportunity for revision based on feedback and reflection proves particularly valuable for learning from mistakes and developing metacognitive awareness.

Integration of PjBL with complementary pedagogical approaches and technologies appears to enhance effectiveness for science literacy development. Studies document successful integration with STEM education frameworks, where projects explicitly connect science content with mathematics, engineering design, and technological tools (Pertiwi et al., 2024; Kurniasari et al., 2023). This interdisciplinary integration reflects the authentic nature of real-world problem-solving while developing broader competencies beyond science content knowledge.

Digital storytelling represents another effective complement to PjBL for science literacy development. Research demonstrates that combining PjBL with digital storytelling significantly enhances students' ability to communicate scientific concepts and interpret scientific information (Munawar et al., 2023). The multimodal nature of digital storytelling engages diverse learner preferences while developing important communication competencies increasingly important in contemporary society. Students must synthesize scientific understanding with narrative structure and visual design, requiring deep processing of content.

The effectiveness of PjBL for science literacy appears consistent across diverse student populations and educational contexts, though some contextual factors influence implementation success. Teacher pedagogical knowledge and skills in facilitating PjBL significantly influence outcomes, with more experienced and well-prepared teachers achieving stronger student learning gains (Karmana, 2024). This suggests that teacher professional development represents a critical investment for successful PjBL implementation at scale.

Comparative research examining PjBL versus Problem-Based Learning found both approaches effectively enhance science literacy, with Problem-Based Learning showing slight advantages for certain conceptual understanding dimensions (Aini, 2022). This suggests that while PjBL represents an effective approach, it should be viewed as one valuable pedagogical tool within a broader instructional repertoire rather than a universal solution. Optimal instruction likely involves strategic use of multiple evidence-based approaches selected based on specific learning objectives and contexts.

Table 2. Effects of Project-Based Learning on Environmental Awareness and Literacy

Focus Area	Specific Outcomes	Implementation Approach	Key Findings	Sources

DOI: https://doi.org/10.62872/80h4ry59

Environmental Awareness	Understanding of local environmental issues, recognition of human-environment connections	Projects addressing local pollution, climate change, waste management	Significant increases in environmental problem understanding and awareness	Khondokar (2025); Pertiwi et al. (2024); Suryawati et al., 2020)
Pro-Environmental Attitudes	Care for environment, concern about environmental degradation, environmental values	Integration of environmental topics in science projects	Statistically significant improvements in environmental care attitudes and values	Khondokar (2025); Munawar et al. (2023); Agustira et al. (2025)
Environmental Action	Willingness to take environmental action, actual pro-environmental behaviors	Action-oriented projects with real environmental interventions	Students demonstrated increased motivation and actual engagement in environmental actions	Suryawati et al. (2020); Agustira et al. (2025); Sawitri et al. (2024)
Environmental Literacy	Integrated knowledge, skills, attitudes, and behaviors related to environment	STEM-based PjBL with environmental focus	Comprehensive improvements across all environmental literacy dimensions	Pertiwi et al. (2024); Agustira et al. (2025)
Systems Thinking	Understanding of interconnections, complexity of environmental systems	Projects requiring analysis of complex environmental problems	Enhanced ability to recognize relationships and understand environmental systems	Suryawati et al. (2020); Agustira et al. (2025)
Character Development	Environmental responsibility, ethical considerations, sustainable values	PjBL integrated with character education and multiliteracy	Development of environmental ethics and responsible citizenship dispositions	Agustira et al. (2025); Pantiwati (2021)

Table 2 demonstrates that Project-Based Learning significantly enhances environmental awareness and literacy through multiple interconnected dimensions including cognitive understanding, affective attitudes, and behavioral intentions and actions. The evidence reveals that PjBL proves particularly effective for environmental education because it enables authentic engagement with real

DOI: https://doi.org/10.62872/80h4ry59
environmental issues in students' communities, creating meaningful connections between abstract environmental concepts and tangible local realities (Khondokar, 2025; Pertiwi et al., 2024).

Environmental awareness development through PjBL begins with enhanced understanding of environmental problems and human-environment relationships. Research from primary social science classrooms in Dhaka demonstrates that students participating in environment-focused PjBL developed significantly deeper understanding of local environmental issues including pollution sources, impacts, and potential solutions (Khondokar, 2025). This enhanced understanding emerged through direct investigation of environmental conditions in students' communities, making abstract environmental concepts concrete and personally relevant.

The effectiveness of PjBL for environmental awareness appears strongly mediated by authentic connection to local environmental contexts. Studies consistently demonstrate that projects addressing specific environmental problems in students' immediate surroundings prove more effective than those dealing with abstract or distant environmental issues (Suryawati et al., 2020; Pertiwi et al., 2024). This local contextualization makes environmental problems tangible and urgent while also developing students' sense of agency and responsibility for their immediate environment. Students recognize that they can contribute meaningfully to environmental solutions rather than feeling powerless in the face of global environmental challenges.

Beyond cognitive understanding, PjBL significantly enhances pro-environmental attitudes including care for the environment, concern about environmental degradation, and valuing of environmental protection. Multiple studies document statistically significant improvements in environmental care attitudes following PjBL implementation, with effect sizes suggesting educationally meaningful changes in students' environmental values (Khondokar, 2025; Munawar et al., 2023; Agustira et al., 2025). These attitudinal shifts represent crucial precursors to behavioral change, as environmental literacy requires not merely knowledge but also motivation and commitment to environmental stewardship.

The development of environmental attitudes through PjBL appears to result from both cognitive and affective processes. As students investigate environmental problems and their impacts, they develop emotional connections and empathy that complement intellectual understanding (Sawitri et al., 2024). Witnessing environmental degradation firsthand or hearing from community members affected by environmental problems creates emotional engagement that purely abstract learning cannot achieve. This integration of cognitive and affective learning proves essential for developing the deep environmental awareness that motivates action.

Perhaps most significantly, PjBL demonstrates effectiveness in cultivating environmental action orientation and actual pro-environmental behaviors, moving beyond knowledge and attitudes to tangible behavioral outcomes. Research documents that students participating in environment-focused PjBL express increased willingness to take environmental action and actually engage in pro-environmental behaviors including waste reduction, recycling, conservation, and environmental advocacy (Suryawati et al., 2020; Agustira et al., 2025). This behavioral dimension represents the ultimate goal of environmental education, as knowledge and attitudes matter primarily insofar as they translate into environmentally responsible action.

The action-orientation of effective environmental PjBL appears crucial for achieving behavioral outcomes. Projects that require students to not merely study environmental problems but actually implement interventions or solutions demonstrate particularly strong effects on environmental action (Agustira et al., 2025). Through designing and implementing environmental projects such as waste reduction campaigns, habitat restoration activities, or environmental awareness raising initiatives, students develop both capacity and commitment for environmental action that persists beyond the formal project timeframe.

STEM-based PjBL represents a particularly effective approach for developing comprehensive environmental literacy that integrates across knowledge, skills, attitudes, and behaviors. Research

DOI: https://doi.org/10.62872/80h4ry59

demonstrates that PjBL incorporating science, technology, engineering, and mathematics in environmental contexts significantly improves students' environmental literacy across all dimensions (Pertiwi et al., 2024). The STEM integration enables students to apply scientific understanding, utilize technological tools, employ engineering design processes, and use mathematical reasoning in addressing authentic environmental challenges, developing sophisticated environmental problem-solving capabilities.

The integration of multiliteracy pedagogies and character education with environmental PjBL further enhances effectiveness by explicitly addressing values, ethics, and citizenship dimensions of environmental literacy (Agustira et al., 2025; Pantiwati, 2021). Projects that deliberately cultivate critical thinking skills, decision-making abilities, ethical reasoning, and civic responsibility alongside environmental content knowledge produce more comprehensive environmental literacy outcomes. This holistic approach recognizes that environmental citizenship requires not merely technical knowledge but also ethical commitment and civic engagement capacities.

Environmental PjBL also develops important systems thinking capabilities that enable students to understand the complexity and interconnectedness of environmental systems. Through investigating multifaceted environmental problems, students learn to recognize relationships between environmental, social, and economic factors, appreciate complexity and uncertainty, and understand that environmental challenges require comprehensive approaches addressing multiple dimensions simultaneously (Suryawati et al., 2020). This systems perspective represents sophisticated understanding essential for addressing contemporary environmental challenges that resist simple solutions.

Key Success Factors and Implementation Considerations

Analysis of factors contributing to successful PjBL implementation for science literacy and environmental awareness reveals several consistent patterns. First, authentic and personally meaningful project topics prove essential for engaging student motivation and facilitating deep learning. Projects addressing real problems that matter to students and their communities generate intrinsic motivation and sustained engagement that abstract or artificial projects cannot achieve (Khondokar, 2025; Melindayani, 2022). Careful project selection and design that considers student interests and local contexts represents a critical success factor.

Second, appropriate scaffolding and support structures enable students to successfully navigate the complexity and ambiguity inherent in authentic projects. While PjBL emphasizes student autonomy and inquiry, complete lack of structure overwhelms many students and impedes learning (Nuraini & Waluyo, 2021). Effective PjBL balances student agency with strategic teacher guidance, providing frameworks, resources, and just-in-time instruction that support productive inquiry without prescribing predetermined paths or conclusions. Teachers must develop sophisticated pedagogical skills to provide appropriate scaffolding that supports without constraining learning.

Third, sufficient time allocation proves necessary for the deep engagement and iterative cycles of investigation, reflection, and refinement that characterize effective PjBL. Projects compressed into inadequate timeframes sacrifice depth for breadth and prevent the sustained engagement necessary for transformative learning (Hudha et al., 2023). Effective PjBL implementation requires fundamental reconsideration of curriculum organization and time allocation, moving away from coverage-oriented approaches toward depth-focused learning that prioritizes understanding over superficial exposure to vast content.

Fourth, appropriate assessment approaches that capture the multidimensional learning outcomes of PjBL prove essential for both evaluating student learning and providing formative feedback that supports learning processes. Traditional assessment focused narrowly on content recall fails to capture the rich learning occurring in PjBL contexts (Karmana, 2024). Effective PjBL assessment employs multiple methods including performance assessments, portfolio evaluation, presentations, and self-

DOI: https://doi.org/10.62872/80h4ry59
reflection that align with the authentic nature of project-based learning and provide meaningful feedback.

Fifth, collaborative learning structures that distribute cognitive load, leverage diverse perspectives, and develop social skills require deliberate design and facilitation. Simply placing students in groups does not ensure productive collaboration (Maslihatin, 2024). Effective PjBL explicitly teaches collaboration skills, structures group processes to ensure equitable participation, and holds students accountable for both individual and collective contributions. Teachers must actively monitor and facilitate group dynamics to prevent common problems such as unequal participation or interpersonal conflicts.

Sixth, integration of appropriate technologies can enhance PjBL effectiveness by expanding information access, enabling sophisticated data analysis and visualization, facilitating communication and collaboration, and supporting creative expression through multimodal artifacts (Munawar et al., 2023; Prakoso & Rusnilawati, 2024). However, technology should serve learning goals rather than become an end in itself. Effective technology integration in PjBL requires thoughtful selection of tools that genuinely enhance rather than distract from core learning objectives.

Implementation challenges that can impede PjBL effectiveness include inadequate teacher preparation and pedagogical content knowledge, insufficient time and resources, assessment systems misaligned with PjBL learning goals, classroom management challenges inherent in active learning environments, and institutional constraints including rigid curriculum requirements and standardized testing pressures (Karmana, 2024). Addressing these challenges requires systemic support including teacher professional development, curriculum reform, assessment innovation, and policy changes that create enabling conditions for effective PjBL implementation.

Conclusion

This comprehensive review provides robust evidence that Project-Based Learning significantly enhances both science literacy and environmental awareness among students across diverse educational levels and contexts. The accumulated empirical evidence demonstrates consistent positive effects that extend beyond isolated studies, with students participating in PjBL showing superior performance in science literacy assessments, deeper conceptual understanding, enhanced critical thinking abilities, and improved problem-solving skills compared to those receiving conventional instruction. For environmental education, PjBL proves particularly powerful by connecting students with authentic local environmental issues, cultivating both cognitive understanding and emotional engagement, developing systems thinking capabilities, and fostering environmental action orientation that translates knowledge and attitudes into concrete pro-environmental behaviors.

Key factors contributing to PjBL effectiveness include authentic and meaningful project topics that address real-world problems, appropriate scaffolding structures that support student inquiry, sufficient time allocation for deep engagement, collaborative learning environments, integration with complementary approaches such as STEM education and digital storytelling, and strategic technology utilization. The effectiveness of PjBL is enhanced when projects address locally relevant issues, particularly for environmental awareness development, and when implementation includes explicit attention to higher-order thinking skills, multiliteracy pedagogies, and character education. However, successful large-scale implementation requires substantial investment in teacher professional development, curriculum reform, aligned assessment practices, and supportive policy frameworks that create enabling conditions rather than barriers.

The implications for educational practice are clear and compelling. Science and environmental education should incorporate well-designed Project-Based Learning experiences that engage students in authentic inquiry addressing real-world problems relevant to their communities and lives. Educational systems must move beyond rhetoric supporting 21st-century skills toward fundamental restructuring that enables transformative pedagogies like PjBL to flourish, including rethinking curriculum organization, assessment systems, and teacher preparation programs. By engaging students in authentic, meaningful projects that connect science learning with pressing challenges including environmental

DOI: https://doi.org/10.62872/80h4ry59
sustainability, education can cultivate not merely knowledgeable students but empowered citizens capable of contributing to creating a more sustainable and just future.

Bibliography

Agustira, D., Al-Muhdhar, M., Lestari, S., & Pratiwi, R. (2025). Development of a project based learning model with multiliteracy pedagogic content to improve critical thinking skills, problem solving skills, decision making skills, and environmental literacy. *Edelweiss Applied Science and Technology*, *9*(3), 1562-1584. https://doi.org/10.55214/25768484.v9i3.5812

Aini, M. (2022). PERBEDAAN LITERASI SAINS SISWA DALAM IMPLEMENTASI MODEL PEMBELAJARAN PROBLEM BASED LEARNING DAN PROJECT BASED LEARNING. *EDUCATOR: Jurnal Inovasi Tenaga Pendidik dan Kependidikan*, *2*(2), 87-95. https://doi.org/10.51878/educator.v2i2.1354

Fauziah, D., Erman, E., Susiyawati, E., & Budiyanto, M. (2023). Implementation of project-based learning models to improve science literacy of junior high school students. *Jurnal Pijar MIPA*, *18*(2), 280-285. https://doi.org/10.29303/jpm.v18i2.4795

Hudha, M., Fajriyah, M., Rosyidah, F., & Ayu, H. (2023). Project-based learning in improving scientific literacy: Systematic literature review. *Psychology, Evaluation, and Technology in Educational Research*, *5*(2), 107-118. https://doi.org/10.33292/petier.v5i2.157

Karmana, W. (2024). Penerapan Model Project Based Learning (PjBL) terhadap Kemampuan Literasi Sains dan Hasil Belajar Peserta Didik pada Pembelajaran IPA di Sekolah. *Panthera: Jurnal Ilmiah Pendidikan Sains dan Terapan*, *4*(2), 54-62. https://doi.org/10.36312/panthera.v4i2.273

Khondokar, S. (2025). Environmental awareness through project-based learning in primary social science classrooms in Dhaka: A qualitative analysis. *Inovacije u nastavi*, *38*(1), 135-149. https://doi.org/10.5937/inovacije2501135s

Kurniasari, R., Ridho, S., & Indriyanti, D. (2023). Analysis of the STEM-Based Blended Project Based Learning Model to Improve Students' Science Literacy. *Journal of Innovative Science Education*, *12*(1), 76-83. https://doi.org/10.15294/jise.v12i1.62296

Maslihatin, L. (2024). PENGEMBANGAN PERANGKAT PEMBELAJARAN PROJECT BASED LEARNING BERBASIS HOTS UNTUK MENINGKATKAN LITERASI SAINS DISEKOLAH DASAR. *EDUTECH: Jurnal Inovasi Pendidikan Berbantuan Teknologi*, *4*(3), 598-609. https://doi.org/10.51878/edutech.v4i3.3287

Melindayani, S. (2022). PENGARUH MODEL PEMBELAJARAN BERBASIS PROYEK TERHADAP KEMAMPUAN LITERASI SAINS MATERI IPA SISWA KELAS V SD TELKOM MAKASSAR. *Jurnal Handayani*, *13*(1), 79-88. https://doi.org/10.24114/jh.v13i1.35821

Munawar, R., Jaenudin, D., & Retnowati, R. (2023). PROJECT-BASED LEARNING WITH DIGITAL STORYTELLING TO IMPROVE SCIENCE LITERACY OF 10TH-GRADE STUDENTS IN MA AL MANSHURIYAH SCHOOL. *Journal of Science Education and Practice*, *7*(1), 45-54. https://doi.org/10.33751/jsep.v7i1.7304

Nuraini, N., & Waluyo, E. (2021). Pengembangan Desain Instruksional Model Project Based Learning Terintegrasi Keterampilan Proses Sains Untuk Meningkatkan Literasi Sains. *Jurnal Ilmiah Pendidikan IPA*, *5*(1), 101-111. https://doi.org/10.24815/jipi.v5i1.20145

DOI: https://doi.org/10.62872/80h4ry59
Pantiwati, Y. (2021). MODEL PEMBELAJARAN LI-PRO-GP (LITERASI BERBASIS PROYEK TERINTEGRASI GLS DAN PPK). *Prosiding Simposium Nasional Multidisiplin (SinaMu)*, *2*, 264-272. https://doi.org/10.31000/sinamu.v2i0.3593

Pertiwi, T., Oetomo, D., & Sugiharto, B. (2024). The effectiveness of STEM Project-Based Learning in improving students' environmental literacy abilities. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(2), 604-614. https://doi.org/10.22219/jpbi.v10i2.33562

Prakoso, N., & Rusnilawati, R. (2024). ANALISIS MODEL PROJECT BASED LEARNING BERBANTUAN LIVEWORKSHEETS DALAM MENINGKATKAN PRESTASI BELAJAR DAN KETERAMPILAN LITERASI SAINS. *Muallimuna: Jurnal Madrasah Ibtidaiyah*, *9*(2), 1-14. https://doi.org/10.31602/muallimuna.v9i2.14304

Salma, I., Hariani, S., & Pujiastuti, P. (2022). Pengaruh Model Pembelajaran Learning Cycle (5E) Berbasis STEM terhadap Literasi Sains dan Hasil Belajar Siswa Kelas X. *DWIJA CENDEKIA: Jurnal Riset Pedagogik*, *6*(2), 269-278. https://doi.org/10.20961/jdc.v6i2.61600

Sawitri, A., Priyanti, P., Wanah, N., & Prayogo, M. (2024). Membangun Generasi Peduli Lingkungan: Analisis Literatur Pembelajaran Sains di Tingkat SD/MI. *INKUIRI: Jurnal Pendidikan IPA*, *13*(1), 39-51. https://doi.org/10.20961/inkuiri.v13i1.80296

Suryawati, E., Suzanti, F., Zulfarina, Z., Putriana, A., & Febrianti, L. (2020). The Implementation of Local Environmental Problem-Based Learning Student Worksheets to Strengthen Environmental Literacy. *Jurnal Pendidikan IPA Indonesia*, *9*(2), 169-178. https://doi.org/10.15294/jpii.v9i2.22892

Tanta, T. (2024). PENGARUH MODEL PEMBELAJARAN CONTEXTUAL TEACHING LEARNING (CTL) BERBASIS PROYEK TERHADAP LITERASI SAINS MAHASISWA PENDIDIKAN BIOLOGI UNIVERSITAS CENDERAWASIH JAYAPURA. *Kwangsan: Jurnal Teknologi Pendidikan*, *11*(2), 604-615. https://doi.org/10.31800/jtp.kw.v11n2.p604--615