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Journal of Current Studies in SDGs
Homepage : https://journal.i-ros.org/index.php/JOCSIS
Email : jocsis@i-ros.org

e-ISSN 3089-7564
Vol.2, No.3, September 2026

Project-Based Learning in Indonesian Junior High School Science Education for SDG 4: Teachers' Perceptions, Practices, and Implementation Challenges

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DOI : https://doi.org/10.63230/jocsis.2.3.265

Sections Info

Article history:
Submitted: March 3, 2026
Final Revised: May 29, 2026
Accepted: July 3, 2026
First Available Online: July 6, 2026
Publication Date: September 27, 2026

Keywords:
Critical Thinking;
Pedagogical Competence;
Project-Based Learning;
Science Education;
SDG 4.

ABSTRACT

Objective: *To explore Indonesian junior high school science teachers' perceptions, practices, and challenges in implementing Project-Based Learning (PjBL) in science education, particularly in relation to the promotion of quality education as reflected in SDG 4. The study also examined the relationship between teaching experience, regional background, teachers' perceptions, and the frequency of PjBL implementation.* ***Method:*** *A survey was conducted involving science teachers from various regions of Indonesia with different teaching experiences. Data were collected using a questionnaire developed based on core PjBL indicators, including project planning, implementation, assessment, and reflection. The data were analyzed using descriptive analysis, chi-square tests, and binomial tests.* ***Results:*** *The findings showed that most science teachers had positive perceptions of PjBL and recognized its potential to enhance student engagement, collaboration, problem-solving, creativity, and critical thinking skills. However, positive perceptions did not automatically lead to frequent classroom implementation. Several challenges were identified, including limited time, varying student readiness, inadequate facilities, difficulties in project assessment, and limited understanding of inquiry-oriented and reflective PjBL practices.* ***Novelty:*** *The study highlights the gap between teachers' positive perceptions and actual PjBL implementation in Indonesian junior high school science education. It contributes to SDG 4 by emphasizing the need for sustained professional development to strengthen teachers' pedagogical competence and support more inclusive, meaningful, and quality science learning.*

INTRODUCTION

The development of science and technology in the 21st century has brought about significant changes in the educational paradigm in various countries. Modern education is no longer solely oriented towards knowledge transfer but also emphasizes the development of 21st-century competencies, such as critical thinking, creativity, collaboration, communication, and problem-solving. (Aldowah et al., 2024; Avdiu et al., 2024; Fitrah et al., 2025; González-Pérez & Ramírez-Montoya, 2022; Thornhill-Miller et al., 2023; Yilmaz et al., 2021). Therefore, current educational practices are increasingly shifting from teacher-centered learning approaches to more student-centered and inquiry-based approaches.

The implementation of Project-Based Learning (PjBL) is also closely aligned with the achievement of Sustainable Development Goal (SDG) 4: Quality Education, which aims to ensure inclusive, equitable, and quality education while promoting lifelong learning opportunities for all. SDG 4 emphasizes learner-centered pedagogies that develop higher-order thinking, creativity, collaboration, and problem-solving competencies required to address increasingly complex global challenges. As one of the recommended student-centered instructional approaches, PjBL provides authentic learning experiences that encourage active participation, inquiry, and collaborative knowledge construction. Consequently, strengthening teachers' capacity to effectively implement PjBL is essential not only for improving science education quality but also for supporting the broader educational transformation needed to achieve SDG 4 in Indonesia.

One learning approach that has gained widespread attention in recent years is Project-Based Learning (PjBL). Based on constructivist theory, PjBL encourages students to actively engage in authentic and meaningful learning experiences through project activities that require investigation, collaboration, decision-making, and problem-solving in real-life contexts. (Kurt & Akoglu, 2023; Rehman et al., 2023; Himes et al., 2023; Ramírez de Dampierre et al., 2024; Sánchez-García & Reyes-de-Cózar, 2025). Through active involvement in the planning, implementation, and evaluation processes of projects, students are encouraged to construct their own understanding while developing higher-order thinking skills and technological competencies.

Various studies show that PjBL has a positive impact on students' conceptual understanding, learning motivation, self-confidence, creativity, and collaborative abilities. (Loyens et al., 2023; Malyuga & Petrosyan, 2022; Nguyen, 2025; Pangestu et al., 2024, Shenbagavalli, 2025, Wijnia et al., 2024, Zhang & Ma, 2023). This holistic learning experience is increasingly relevant in the context of Education 5.0, which emphasizes technology-based, human-centered education, and responsiveness to the social needs of society. In this context, PjBL is seen as relevant for preparing students to face the complexities and challenges of modern society while supporting the development of lifelong learning competencies and sustainable development (Alarfaj et al., 2024; Hussein, 2021).

In the context of Natural Science (IPA) learning at the Junior High School (SMP) level, the implementation of PjBL is crucial because science learning emphasizes not only mastery of theoretical concepts but also the development of science process skills and contextual problem-solving abilities. Science learning requires students to actively observe natural phenomena, conduct experiments, analyze data, and communicate their findings. Therefore, a learning model that can encourage active student involvement and provide authentic learning experiences is needed to improve the quality of science learning. Project-Based Learning (PjBL) has great potential to connect science concepts to students' daily lives and the environment around them. Through project activities such as experiments, observations, and the creation of science-based products, students can develop science process skills while increasing their motivation and engagement in learning. However, the success of Project-Based Learning (PjBL) implementation is greatly influenced by teacher readiness and perception. Teachers play a central role in designing meaningful projects, facilitating collaborative learning, managing classroom dynamics, and conducting authentic assessments throughout the learning process(Pratiwi et al., 2024; Masbukhin et al., 2023).

Teachers' perceptions of a learning innovation are a crucial factor influencing its successful implementation in the classroom. Positive perceptions can encourage teachers to be more open to pedagogical innovation, while less positive perceptions can hinder the implementation of the learning model. Teachers' perceptions of PjBL can be influenced by various factors, such as teaching experience, pedagogical understanding, professional training, school institutional support, and the availability of learning facilities and infrastructure. Therefore, understanding teacher perceptions is crucial for identifying opportunities and obstacles in implementing PjBL in schools (Subiyantoro, 2023; Awaliyah, 2025).

Although various studies have examined the effectiveness of PjBL on improving students' learning outcomes and 21st-century skills, research specifically exploring the perceptions, practices, and challenges of PjBL implementation among junior high school science teachers in Indonesia is still relatively limited. Most previous studies have focused more on student learning outcomes and the effectiveness of learning interventions, while studies on teachers' cognitive, affective, and conative dimensions of PjBL implementation are still limited, especially in the context of science education in Indonesia. Yet, teachers' beliefs and attitudes have a direct influence on the sustainability and effectiveness of learning reforms in schools (Permadi et al., 2025; Chen, 2024).

In line with the curriculum policy in Indonesia that emphasizes active and student-centered learning, the implementation of PjBL is increasingly encouraged in educational practice. However, its implementation in the field remains uneven and faces various pedagogical and technical challenges. Therefore, this study aims to explore the perceptions of junior high school science teachers in Indonesia towards PjBL from the cognitive, affective, and conative dimensions, and to identify the experiences and challenges faced by teachers in implementing PjBL in science learning. The results of this study are expected to contribute to the development of teacher competency strengthening programs and serve as a basis for developing more innovative, effective, and relevant science learning practices to meet the demands of 21st-century education (Chen, 2024; Giamellaro et al., 2025).

RESEARCH METHOD

Research design

This study used a qualitative descriptive approach supported by simple quantitative analysis to explore junior high school science teachers' perceptions of PjBL. This study focused on three dimensions of perception: cognitive, affective, and conative. The cognitive dimension relates to teachers' knowledge and beliefs regarding the concept and implementation of PjBL; the affective dimension relates to teachers' feelings, attitudes, and level of acceptance toward PjBL; and the conative dimension relates to teachers' tendencies and intentions to implement PjBL in classroom learning practices.

A qualitative descriptive approach was chosen because it allowed researchers to explore participants' subjective experiences, interpretations, and perspectives in greater depth within the natural context of science learning practices. Furthermore, simple quantitative analysis was used to support the interpretation of the questionnaire data and strengthen the research's descriptive findings.

Research participants

Participants in this study were science teachers teaching in junior high schools (SMP), both public and private, from several regions in Indonesia. Participants were selected using a purposive sampling technique based on the following criteria: (1) actively teaching science at the junior high school level, and (2) having experience implementing or at least understanding the concept of Project-Based Learning in teaching.

The study involved 36 science teachers. The study was conducted in 2022 through online data collection. The diversity of participants' educational backgrounds and teaching experiences is expected to provide a broader picture of teachers' perceptions and practices regarding the implementation of Project-Based Learning (PjBL) in the context of science education in Indonesia.

Data collection techniques and research instruments

Data collection was conducted using an online questionnaire distributed through Microsoft Forms. The use of online questionnaires allowed researchers to reach participants from various regions in Indonesia more effectively and efficiently.

Respondents were asked to complete the questionnaire based on their experiences and perspectives regarding the implementation of PjBL in science learning. The questionnaire consisted of 10 closed-ended and open-ended questions covering several aspects: (1) teachers' understanding and perceptions of PjBL, (2) teachers' experiences in implementing PjBL, and (3) challenges and obstacles encountered during PjBL implementation.

The research instrument was developed by the researchers based on the research objectives and a review of relevant literature on PjBL and teachers' perceptions. Prior to use, the instrument was reviewed to ensure clarity of language, appropriateness of content, and relevance to the research objectives.

Data analysis techniques

The data obtained were analyzed descriptively using qualitative and quantitative approaches. Quantitative data derived from closed-ended questionnaire responses were analyzed using the chi-square correlation test and the binomial test to identify patterns and tendencies in teacher responses related to the implementation of PjBL. Meanwhile, qualitative data obtained from open-ended responses were analyzed using thematic content analysis. The analysis was carried out through several stages, namely data reduction, coding, category grouping, theme identification, and interpretation of emerging patterns related to teachers' cognitive, affective, and conative perceptions of PjBL. To facilitate interpretation and presentation of the research results, the findings of the thematic analysis were also visualized using a conceptual web model to illustrate the relationships between themes and categories found in the study.

RESULTS AND DISCUSSION

Results

Overview of participants

The characteristics of the research participants are presented in Table 1. The majority of respondents were female science teachers (75.00%), while male teachers accounted for 25.00%. Based on age range, the majority of respondents were between 26–30 years (38.90%) and 36–40 years (36.10%), while the 31–35 age group accounted for 25.00%. In terms of educational attainment, almost all participants had a bachelor's degree (S1/D-IV) (97.20%), while only a small proportion had completed a master's degree (2.80%).

These findings indicate that the research participants were predominantly teachers of productive age with undergraduate educational backgrounds, thus providing an overview of the implementation of PjBL in the context of science learning practices at the junior high school level.

Table 1. Participant characteristics

Characteristics	Category	Percentage (%)
Characteristics	Male	25.00
Gender	Female	75.00
	26–30 years	38.90
Age	31–35 years	25.00
	36–40 years	36.10

Characteristics	Category	Percentage (%)
Educational Level	Bachelor's Degree (S1/D-IV)	97.20
	Master's Degree (S2)	2.80

Science teachers' perceptions of the implementation of the PjBL model

The perceptions of junior high school science teachers towards the implementation of PjBL were analyzed based on three main dimensions, namely cognitive, affective, and conative dimensions.

1. Cognitive dimension: Teachers' knowledge and beliefs towards PjBL

The analysis results in Figure 1 indicate that teachers' abilities in implementing PjBL tend to be stronger at the project planning and idea development stages. Conversely, teachers' abilities remain relatively low in the overall project management and project alignment aspects with learning competency standards. This finding indicates that most teachers already have a conceptual understanding of PjBL, but still need capacity building in the technical implementation and learning evaluation aspects so that PjBL implementation can be more comprehensive and effective.

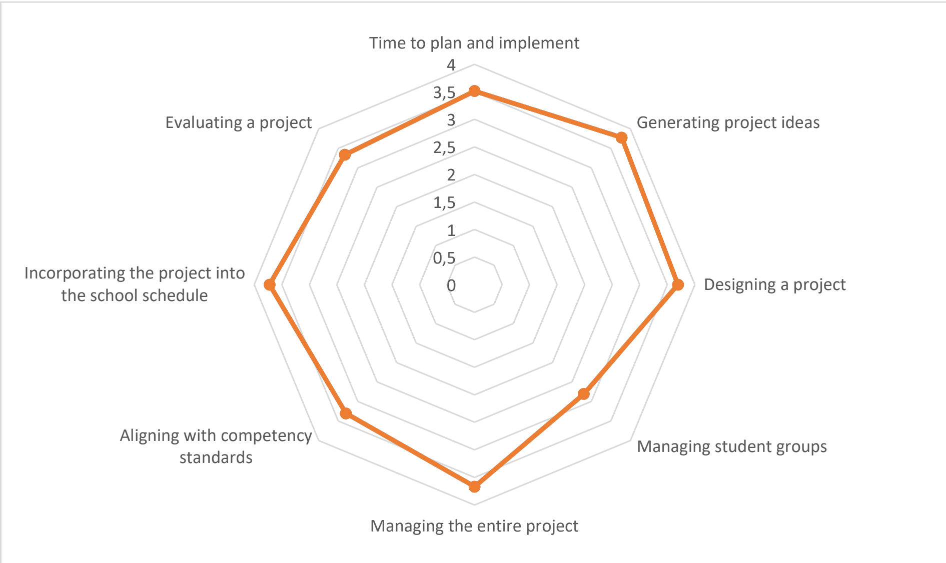

Figure 1. Science teachers' perceptions of PjBL implementation

Teachers' perceptions of 21st-century skills, as presented in Figure 2, show that creativity and innovation scored highest, followed by critical thinking and problem-solving skills. This indicates that teachers have strong confidence in their ability to generate new ideas and facilitate problem-solving in science learning. Conversely, technology and information literacy and leadership and responsibility scored relatively lower than the other aspects. This finding suggests that the use of digital technology in learning and the strengthening of leadership roles in collaborative learning still need improvement. Meanwhile, communication and collaboration and social and cross-cultural skills ranked in the moderate to high category, indicating that social interaction and cooperation among students have developed quite well, although there is still room for improvement. Overall, this profile indicates that teachers' cognitive dimensions related to innovation and thinking processes are well developed, but strengthening the technology and leadership dimensions is still needed to support more holistic 21st-century learning.

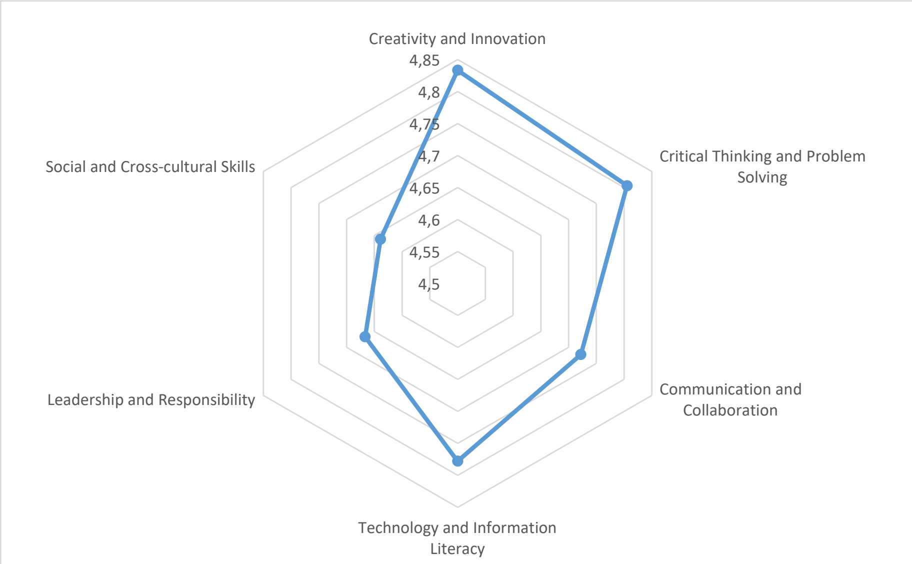

Figure 2. Science teachers' perceptions of the PjBL model towards 21st century skills

2. Affective Dimension: Teachers' Attitudes and Feelings towards PjBL

The binomial test results presented in Table 2 show that the majority of teachers responded "Strongly Agree" to most aspects of 21st-century skills measured. The aspects of creativity and innovation, critical thinking and problem-solving, communication and collaboration, and technology and information literacy showed a high proportion of "Strongly Agree" responses (≥ 0.72) with a significance value of $p < 0.05$. This finding indicates that teachers have a positive attitude and a high level of belief in the importance of developing 21st-century skills through the implementation of PjBL. However, the aspects of leadership and responsibility ($p = 0.065$) and social and cross-cultural skills ($p = 0.132$) did not show significant differences. This indicates that teachers' perceptions of these two aspects are still relatively varied and not yet fully established. Overall, these results show that teachers' affective dimensions towards PjBL tend to be positive, especially in the cognitive and collaborative aspects. However, the social, leadership, and cross-cultural interaction dimensions still require strengthening through professional training and more collaborative learning experiences.

Table 2. Results of the binomial test of 21st century skills aspects based on science teacher responses

Variable	Response	Amount	Proportion	p
Creativity and Innovation	S	6	0.167	< 0.001
	SS	30	0.833	< 0.001
Critical Thinking and	S	7	0.194	< 0.001
Problem Solving	SS	29	0.806	< 0.001
Communication and	S	10	0.278	0.011
Collaboration	SS	26	0.722	0.011
Technology and	S	8	0.222	0.001
Information Literacy	SS	28	0.778	0.001
Leadership and	S	12	0.333	0.065
Responsibility	SS	24	0.667	0.065
Social and cross-cultural	S	13	0.361	0.132
skills	SS	23	0.639	0.132

3. Conative dimension: Teacher practice tendencies in implementing PjBL

The relationship between teachers' perceptions of PjBL and the frequency of PjBL implementation is presented in Table 3. Most teachers have a very positive perception of PjBL, but implementation in learning practices is still relatively rare.

Table 3. The relationship between teacher perceptions and the frequency of PjBL implementation

Teacher perceptions	Frequency of application of the PjBL model			
	Never	Seldom	Often	Total
Can be positive, can be negative	0	2	0	2
Very positive	3	18	2	23
Generally positive	1	8	2	11
Total	4	28	4	36

The chi-square test results, as presented in Table 4, indicate no significant relationship between teachers' perceptions of PjBL and the frequency of its implementation in learning ($p > 0.05$). Although most teachers have very positive perceptions of PjBL, its implementation in the classroom is still limited. This finding suggests that teachers' positive perceptions do not automatically encourage intensive PjBL implementation. Other factors such as technical readiness, time constraints, administrative burden, school support, and the availability of learning facilities likely have a greater influence on PjBL implementation in science learning practices.

Table 4. Chi-Square correlation between teachers' perceptions of PjBL and the frequency of PjBL implementation

Coefficient	N	Value	df	p
X^2	36	1.342	4	0.854

Science teachers' experience in implementing PjBL

The experience of science teachers in implementing PjBL was analyzed based on two main dimensions, namely teaching experience and region of origin.

1. Teaching experience and PjBL implementation

The analysis results in Table 5 indicate that teachers with 6–15 years of teaching experience tend to implement PjBL more frequently than other groups. However, the chi-square test results, as presented in Table 6, indicate that this relationship is not statistically significant ($p > 0.05$). This finding suggests that length of teaching experience does not directly determine the intensity of PjBL implementation among junior high school science teachers.

Table 5. The relationship between length of teaching and frequency of PjBL implementation

Length of Teaching	**Frequency of application of the PjBL model**			
	Never	**Seldom**	**Often**	**Total**
1-5 years	1	8	0	9
11-15 years	1	7	4	12
16-20 years	0	1	0	1
6-10 years	2	12	0	14
Total	**4**	**28**	**4**	**36**

Table 6. Chi-Square correlation between the length of teaching experience of science teachers and the frequency of application of the PjBL model

Coefficient	N	Value	df	p
X^2	36	9.224	6	0.161

2. Regions of origin and PjBL implementation

The analysis of the relationship between respondents' region of origin and the frequency of PjBL implementation, as presented in Tables 7 and 8, shows no statistically significant relationship ($p > 0.05$). However, descriptively, it appears that most respondents from various regions still rarely apply PjBL in their learning. These results indicate that PjBL implementation still faces relatively similar challenges across Indonesia, necessitating a more equitable and contextual implementation strengthening strategy. However, descriptively, it appears that most respondents from various regions still rarely apply PjBL in their learning. These results indicate that PjBL implementation still faces relatively similar challenges across Indonesia, necessitating a more equitable and contextual implementation strengthening strategy.

Table 7. The relationship between region of origin and frequency of PjBL implementation

Regional Origin	Frequency of application of the PjBL model			
	Never	Seldom	Often	Total
Bali, NTB, dan NTT	0	3	1	4
Java and Madura	1	7	0	8
Kalimantan	0	3	0	3
Maluku and North Maluku	0	0	1	1
Papua, West Papua, Mountainous Papua, Central Papua, and South Papua	2	5	2	9
Sumatra, Bangka-Belitung, and the Riau Islands	1	10	0	11
Total	**4**	**28**	**4**	**36**

Table 8. Chi-Square correlation between teaching class and frequency of PjBL implementation

Coefficient	N	Value	df	p
X^2	36	15,08	10	0,129

Barriers for science teachers in implementing PjBL

Science teachers face various challenges in implementing PjBL, including limited learning time, differences in student readiness, limited facilities and infrastructure, and difficulties in conducting project assessments (see Table 9). Furthermore, the correlation between technical aspects of PjBL implementation shows a strong relationship between project management skills, alignment with competency standards, and project integration into the school's learning schedule. These findings suggest that the success of PjBL implementation depends not only on the ability to design projects, but also on teachers' ability to integrate projects with the curriculum, classroom management, and an effective assessment system.

Table 9 Correlation results of technical aspect components of PjBL implementation

Technical Aspects of PjBL Implementation	Coming up with project ideas	Designing projects	Manage groups of students	Manage the entire project	Align with competency standards	Implementing projects into the school schedule	Assess the project
Coming up with project ideas							
Designing projects	0,543***						
Manage groups of students	0,106	0,334*					
Manage the entire project	0,265	0,289	0,465**				
Align with competency standards	0,312	0,482**	0,443**	0,610***			
Implementing projects into the school schedule	0,317	0,361*	0,325	0,643***	0,635***		
Assess the project	0,464**	0,314	0,392*	0,421	0,240	0,346*	

Note for Table 9: * p < .05, ** p < .01, *** p < .001

Table 10 presents the results of the analysis of teachers' open-ended responses, which indicate several misconceptions in understanding the basic concepts of PjBL. In general, misconceptions in PjBL implementation indicate that some teachers still understand PjBL only as product-based learning, rather than as a process of in-depth investigation into authentic problems. Furthermore, PjBL implementation is often not optimally integrated with learning outcomes and core concepts of the science curriculum. Teachers' difficulties in maintaining consistent student engagement and ensuring project coherence also indicate that learning projects are often not designed systematically and sustainably. These findings indicate the need to strengthen teachers' pedagogical competencies through ongoing professional training so that PjBL implementation truly reflects the principles of inquiry-based learning, in-depth reflection, and the holistic development of 21st-century skills.

Table 10. Correlation results of technical aspect components of PjBL implementation

Categories of Teacher Understanding Errors	Teacher Statement (Excerpt from Data)	Academic Justification
Focus on Product	Teachers often emphasize output in the form of products. However, one of the challenges is "Time in project creation, product results in the project".	A common misconception of PjBL is to emphasize the product rather than the deep learning process. Effective PjBL focuses on what students can research and discover (learning), not just what they can create (doing a project). Excessive focus on the product can ignore the main goal of integrating core scientific concepts.
Project Coherence	Challenges include students not	This challenge often occurs when the PjBL units implemented by teachers (especially less experienced

Categories of Teacher Understanding Errors	Teacher Statement (Excerpt from Data)	Academic Justification
	consistently following the schedule and students who do not finish.	teachers) are simply a collection of poorly connected lessons and not a coherent research project. Strong coherence, supported by good Driving Questions, is necessary to maintain student persistence and ensure solid understanding.

Discussion

The results of the study indicate that junior high school science teachers in Indonesia have a positive perception of the implementation of PjBL, particularly in supporting the development of 21st-century skills such as creativity, innovation, critical thinking, and problem-solving. This finding aligns with various recent studies that suggest that PjBL can improve higher-order thinking skills, student engagement, and student engagement. belajar, dan kemampuan pemecahan masalah siswa melalui aktivitas pembelajaran yang autentik dan kontekstual (Kurt & Akoğlu, 2023; Zhang & Ma, 2023). In the context of science learning, student involvement in real-world problem-based projects allows for the active construction of knowledge through scientific investigation, collaboration, and reflection.

Although teachers' perceptions of PjBL tend to be very positive, this study found that the implementation of PjBL in learning practices remains relatively low. The lack of a significant relationship between teachers' perceptions and the frequency of implementation indicates that positive beliefs about learning innovations do not automatically encourage implementation in the classroom. This condition indicates a gap between teachers' pedagogical beliefs and actual learning practices. Several factors such as time constraints, student readiness, administrative burden, limited facilities, and lack of professional training are likely major obstacles to optimal PjBL implementation. (Azevedo et al., 2025; Oduro et al., 2024).

This study also showed that aspects of technology and information literacy, as well as leadership and responsibility, scored lower than other 21st-century skills. This finding indicates that the integration of digital technology in PjBL implementation is still suboptimal. In the context of Education 5.0, technology integration is a crucial element in creating collaborative, adaptive learning that is oriented toward solving real-world problems (Nayak et al., 2024). Therefore, strengthening teachers' digital competencies is a crucial need so that the implementation of PjBL can run more effectively and be relevant to the demands of modern education.

In addition to technical challenges, this study found teachers' misconceptions about the basic concepts of Project-Based Learning (PjBL). Some teachers still understand PjBL as a product-oriented learning process, rather than as an in-depth investigation of authentic problems. Teachers' difficulties in maintaining project coherence and sustained student engagement indicate that PjBL implementation is often not optimally integrated with learning objectives and curriculum outcomes. These findings suggest that the success of PjBL depends not only on the ability to design projects, but also on teachers' pedagogical skills in managing inquiry-based learning, authentic assessment, and student collaboration (Dole et al., 2015; Widarbowo et al., 2023).

Overall, this study confirms that junior high school science teachers in Indonesia have good conceptual readiness for PjBL implementation, but still face various pedagogical and technical challenges in their learning practices. Therefore, continuous strengthening of teacher professional development is needed, particularly in aspects of project design, technology integration, authentic assessment, and collaborative learning management. Furthermore, school institutional support and educational policies that encourage active and student-centered learning are also important factors in optimizing PjBL implementation in science learning in Indonesia.

The findings of this study also have important implications for the achievement of Sustainable Development Goal (SDG) 4: Quality Education, which emphasizes inclusive, equitable, and high-quality learning opportunities for all. The positive perceptions of teachers toward Project-Based Learning (PjBL) demonstrate a strong foundation for promoting student-centered pedagogies that foster critical thinking, creativity, collaboration, and problem-solving competencies required for sustainable development. However, the identified gaps between teachers' positive perceptions and actual classroom implementation highlight the need for continuous professional development, institutional support, and improved digital readiness to ensure effective adoption of PjBL. Strengthening teachers' pedagogical and technological competencies will not only improve the quality of science education but also contribute to developing learners who possess the knowledge, skills, and values necessary to address future social, environmental, and economic challenges, thereby supporting the successful realization of SDG 4 in the Indonesian educational context.

CONCLUSION

Fundamental Finding: This study demonstrates that junior high school science teachers in Indonesia generally hold positive perceptions of Project-Based Learning (PjBL) and recognize its potential to foster 21st-century competencies, including creativity, critical thinking, problem-solving, communication, and collaboration. However, these positive perceptions are not consistently translated into classroom practice. The findings reveal that the implementation of PjBL remains constrained by systemic challenges rather than by teachers' attitudes, as no significant relationships were found between teachers' perceptions, teaching experience, regional background, and implementation frequency. Misconceptions regarding PjBL as a product-oriented rather than an inquiry-based learning approach also remain evident. **Implication:** These findings highlight the importance of strengthening continuous professional development programs that focus on authentic project design, inquiry-based pedagogy, digital technology integration, collaborative learning management, and authentic assessment. Institutional support and educational policies should provide adequate resources and training to facilitate effective PjBL implementation. Enhancing teachers' pedagogical and technological competencies will contribute to improving science education quality and support the achievement of Sustainable Development Goal (SDG) 4, which promotes inclusive, equitable, and quality education through student-centered and meaningful learning experiences. **Limitation:** This study involved a relatively small number of participants from selected regions in Indonesia and relied primarily on self-reported questionnaire data, which may not fully represent teachers' actual classroom practices. In addition, the cross-sectional design limits the ability to examine changes in teachers' perceptions and implementation over time. **Future Research:** Future studies should involve larger and more diverse samples across different educational levels and regions to improve the generalizability of the findings. Mixed-methods or longitudinal research is also recommended to explore how professional development, institutional support, and digital readiness influence the sustainability and effectiveness of PjBL implementation. Further investigation into the contribution of PjBL toward achieving SDG 4, particularly in improving learning quality, educational equity, and students' sustainability competencies, would provide valuable insights for educational policy and practice.

ACKNOWLEDGEMENTS
The authors would like to sincerely thank all teachers who participated in this study for their valuable contributions. The authors also appreciate the support of the schools and educational institutions that facilitated the data collection process.

AUTHOR CONTRIBUTIONS
Martini: Conceptualization, methodology, investigation, data curation, formal analysis, writing original draft, and visualization. **Erman:** Supervision, validation, writing review and editing, and project administration. **I Gusti Made Sanjaya:** Conceptualization, methodology, supervision, validation, writing review and editing, and resources. All authors have read, reviewed, and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

CONFLICT OF INTEREST STATEMENT
The authors declare no conflicts of interest.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING
AI tools were used only for language editing, grammar improvement, and discussion support. The authors take full responsibility for all aspects of the research and the final content of the manuscript.

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