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# Student Learning Experiences in Project-Based Learning in Science

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## Abstract

Science education in the twenty-first century requires instructional approaches that encourage active participation, critical thinking, and meaningful learning experiences. One approach that supports these objectives is Project-Based Learning (PjBL), which positions students as active participants in solving real-world problems through collaborative projects. This study aims to analyze students' learning experiences during the implementation of Project-Based Learning in science subjects. The research employed a qualitative descriptive design to explore students' engagement, collaboration, autonomy, and challenges encountered during project activities. Data were collected through classroom observations, semi-structured interviews, and documentation of students' project work. The data were analyzed using thematic analysis to identify patterns related to students' learning experiences in the PjBL environment. The findings indicate that Project-Based Learning enhances students' engagement and participation in science learning. Students become more active in discussions, collaborative problem-solving, and experimentation, which contributes to deeper conceptual understanding and improved scientific literacy. In addition, PjBL encourages learning autonomy and the development of twenty-first century skills such as critical thinking, teamwork, and creativity. However, some challenges were identified, particularly related to time management and coordination within project groups. Overall, the study concludes that Project-Based Learning provides meaningful and interactive learning experiences that support both cognitive and affective development in science education.

**Keywords**:
Project-Based Learning, Science Education, Students' Learning Experience, Student-Centered Learning, Collaborative Learning

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## 1. INTRODUCTION

Science education in the twenty-first century increasingly emphasizes the importance of learning approaches that place students at the center of the learning process. The rapid development of science and technology requires students not only to master conceptual knowledge but also to develop critical thinking, creativity, and problem-solving skills that enable them to apply scientific knowledge in real-world contexts. However, classroom practices in many educational settings still rely heavily on teacher-centered instruction, where teachers dominate the learning process through lectures and direct explanations. While this approach can be effective for transmitting factual knowledge, it often limits opportunities for students to actively engage in inquiry, experimentation, and collaborative learning experiences that are essential for meaningful science learning (Mutanga, 2024).

The dominance of teacher-centered approaches in science education has been widely criticized because it does not adequately support the development of higher-order thinking skills. In many classrooms, students tend to become passive recipients of information rather than active constructors of knowledge. As a result, learning activities often emphasize memorization of scientific facts instead of exploration and application of scientific concepts. Such instructional practices reduce students' opportunities to develop analytical reasoning and creativity, which are crucial competencies in contemporary science education. Consequently, educational researchers and practitioners have increasingly called for the adoption of student-centered learning approaches that encourage active participation and deeper engagement with scientific content (Bhardwaj et al., 2025).

Student-centered learning (SCL) has emerged as an important paradigm in modern education because it emphasizes students' autonomy, active involvement, and responsibility in constructing knowledge. In this approach, the role of the teacher shifts from being the primary source of knowledge to a facilitator who guides students in exploring ideas, solving problems, and reflecting on their learning experiences. Contemporary reviews of science education research indicate that student-centered strategies significantly enhance student engagement, promote self-regulated learning, and strengthen teacher–student relationships. These elements contribute to a more meaningful and interactive learning environment that supports both cognitive and affective development among students (Santos, 2025).

Despite its theoretical advantages, the implementation of student-centered learning in science classrooms remains challenging. Many teachers encounter difficulties in designing instructional activities that effectively facilitate active learning while still meeting curriculum requirements. Limited resources, insufficient professional development opportunities, and the lack of authentic assessment practices often hinder the successful implementation of student-centered approaches. As a result, although educational policies increasingly advocate student-centered pedagogy, actual classroom practices frequently continue to reflect traditional instructional models. These challenges highlight the need for innovative instructional strategies that can operationalize the principles of student-centered learning in practical classroom contexts (Santos, 2025).

One instructional approach that has gained significant attention in science education is Project-Based Learning (PjBL). PjBL is a student-centered pedagogical model that organizes learning activities around complex projects that require students to investigate real-world problems and develop meaningful solutions. Through collaborative inquiry, experimentation, and reflection, students actively construct knowledge while applying scientific concepts to authentic contexts. This learning model encourages students to take responsibility for their own learning processes and to develop skills such as collaboration, communication, and problem solving that are essential for scientific inquiry (Mutanga, 2024).

The effectiveness of Project-Based Learning in improving students' conceptual understanding and learning engagement has been widely documented in recent studies. Research shows that students who participate in PjBL activities tend to demonstrate stronger conceptual comprehension and greater ability to apply scientific theories to practical situations. Moreover, PjBL encourages collaborative learning environments where students learn from each other through discussion and shared problem solving. These learning experiences not only strengthen academic achievement but also foster independence and responsibility in learning (Beltrán et al., 2025).

In addition to improving conceptual learning outcomes, PjBL has been shown to support the development of essential competencies associated with twenty-first century education. The collaborative nature of project-based activities allows students to develop teamwork and communication skills, while the problem-solving processes embedded in project work stimulate critical thinking and analytical reasoning. Students are also encouraged to explore creative solutions to complex problems, which enhances their innovative capacity and intellectual curiosity. Consequently, PjBL has become an increasingly popular instructional approach in science and STEM education contexts (Rehman et al., 2024).

Recent research also highlights the potential of integrating PjBL with innovative pedagogical frameworks such as design thinking and digital learning environments. In STEM and artificial intelligence education, the combination of design thinking and project-based learning has been shown to stimulate students' imagination, curiosity, and motivation. Such integrative approaches encourage students to view scientific learning as a creative and exploratory process rather than merely an accumulation of theoretical knowledge. These findings indicate that PjBL not only enhances cognitive learning outcomes but also fosters positive emotional and motivational experiences among students (Jiang & Pang, 2023).

Although the effectiveness of Project-Based Learning has been widely acknowledged, most previous studies primarily focus on measurable academic outcomes such as test scores, conceptual understanding, and skill development. While these indicators are important, they do not fully capture the complexity of students' learning experiences during project-based activities. Learning experiences encompass various dimensions, including emotional engagement, collaboration dynamics, challenges encountered during project work, and the development of students' sense of agency in learning. Understanding these experiential aspects is essential for evaluating the true impact of PjBL in science education (Mutanga, 2024).

Several recent reviews of student-centered learning research emphasize that the subjective experiences of students remain underexplored in educational studies. Much of the existing literature examines the effectiveness of instructional models in terms of achievement outcomes, instructional design, or teacher perspectives. However, fewer studies investigate how students themselves perceive and experience the learning process within student-centered pedagogical environments. As a result, there is still limited empirical evidence regarding how student-centered learning strategies influence students' emotional engagement, motivation, and sense of autonomy in learning (Santos, 2025).

The lack of focus on students' lived learning experiences is particularly evident in research on Project-Based Learning in STEM education. While many studies highlight the benefits of PjBL in promoting collaboration and problem solving, only a small number of studies explore how students navigate the challenges of self-directed learning, project selection, and collaborative decision making. These aspects are crucial because students' experiences in managing projects and interacting with peers significantly shape their learning outcomes and personal development (Tang et al., 2024).

Furthermore, recent studies emphasize that the quality of students' learning experiences is closely related to their motivation, satisfaction, and long-term academic success. Positive learning experiences contribute to stronger engagement and deeper understanding, whereas negative experiences may lead to frustration and reduced motivation. Therefore, exploring students' perceptions and experiences during learning activities is essential for designing instructional approaches that support both academic achievement and student well-being (Closs et al., 2021).

Research on student experience also suggests that learning should be understood as a holistic process involving cognitive, emotional, social, and environmental dimensions. Students' interactions with peers, teachers, learning resources, and classroom environments all influence how they interpret and respond to learning activities. Consequently, examining students' learning experiences provides valuable insights into the effectiveness of instructional strategies beyond traditional performance indicators (Napitupulu, 2025).

In the context of science education, investigating students' experiences in Project-Based Learning is particularly important because science learning often involves complex problem solving and collaborative inquiry. Students must not only understand theoretical concepts but also apply them in practical contexts, negotiate ideas with peers, and overcome challenges encountered during project work. These processes create rich learning experiences that shape students' attitudes toward science and influence their long-term engagement with scientific learning (Amimaruddin & RuditaIdris, 2021).

Despite the growing body of literature on student-centered learning and project-based instruction, there remains a significant research gap concerning how students experience these learning approaches in real classroom settings. Many existing studies emphasize the effectiveness of instructional models without examining the subjective and contextual dimensions of learning experiences. This gap indicates the need for research that explores students' perspectives, emotions, and interactions during project-based learning activities in science education (Subiyantoro, 2024).

Addressing this gap is important not only for theoretical development but also for improving instructional practice. By understanding students' experiences during PjBL implementation, educators can identify the factors that facilitate or hinder effective learning processes. Such insights can inform the design of learning environments that better support student engagement, collaboration, and independent inquiry. Consequently, investigating students' learning experiences provides a more comprehensive understanding of how student-centered learning models operate in practice (Tang et al., 2024).

Based on the research gap identified above, this study offers a novel contribution by focusing on students' learning experiences in Project-Based Learning within science education. Unlike many previous studies that primarily evaluate academic outcomes, this research explores how students perceive, engage with, and navigate the learning process during project-based activities. By emphasizing experiential dimensions of learning, the study aims to provide deeper insights into the pedagogical dynamics of PjBL and its influence on students' cognitive and emotional engagement.

Therefore, the main objective of this study is to analyze students' learning experiences during the implementation of Project-Based Learning in science subjects. Through this investigation, the study seeks to contribute to the growing body of research on student-centered pedagogy by highlighting how project-based learning shapes students' engagement, collaboration, and understanding of scientific concepts. The findings are expected to provide valuable implications for improving instructional practices and supporting more meaningful science learning in contemporary educational contexts.

## 2. METHOD

This study employed a qualitative descriptive research design to explore students' learning experiences during the implementation of Project-Based Learning (PjBL) in science education. The qualitative approach was chosen because the primary objective of the study was to understand students' perceptions, engagement, and challenges during the learning process rather than to measure learning outcomes quantitatively. The research was conducted in a science classroom where Project-Based Learning was implemented as the primary instructional strategy. The participants consisted of students who were actively involved in project-based activities during the science learning process. Participants were selected using purposive sampling to ensure that the students included in the study had direct experience with the PjBL approach. Data collection was carried out through several techniques, including classroom observations, semi-structured interviews, and documentation analysis. Classroom observations were conducted to examine students' interactions, collaboration, and engagement during project activities. Semi-structured interviews were used to capture students' perceptions, feelings, and reflections regarding their learning experiences in the PjBL environment. In addition, documentation such as students' project reports, reflective journals, and learning artifacts were analyzed to provide additional contextual information about the learning process.

The data analysis in this study followed a qualitative thematic analysis procedure to identify patterns and meanings within the collected data. First, all observation notes, interview transcripts, and documents were organized and transcribed systematically. Second, the data were coded to identify key themes related to students' learning experiences, such as engagement, collaboration, problem-solving processes, challenges encountered, and perceived learning benefits. Third, the coded data were categorized into broader thematic patterns that reflected students' cognitive, emotional, and social experiences during Project-Based Learning. To ensure the credibility and validity of the findings, data triangulation was applied by comparing information obtained from observations, interviews, and documentation. The interpretation process emphasized identifying meaningful relationships between students' experiences and the characteristics of the PjBL learning environment. Through this analytical procedure, the study aimed to provide a comprehensive understanding of how Project-Based Learning shapes students' learning experiences in science education.

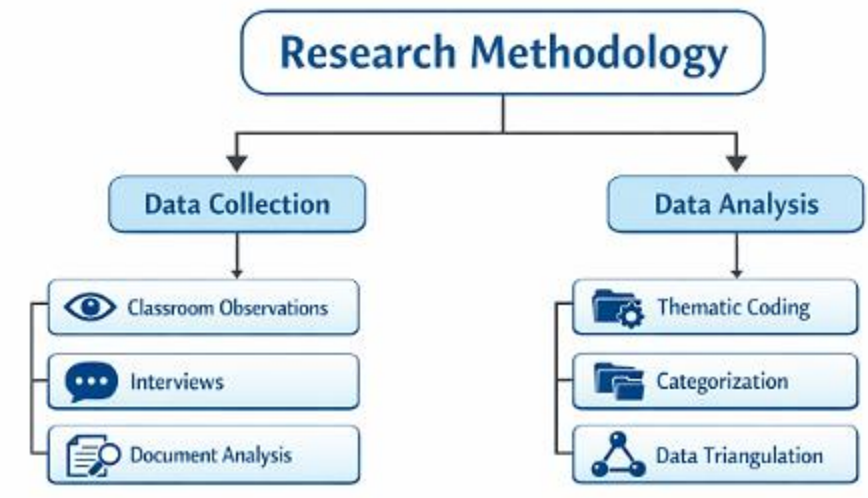


**Figure 1.** Journal of Learning Spectrum

## 3. RESULTS AND DISCUSSION

### 3.1. Results

To understand students' learning experiences during the implementation of Project-Based Learning (PjBL) in science classes, the data obtained from classroom observations, interviews, and document analysis were organized into several thematic categories. The analysis focused on key dimensions of students' learning experiences, including engagement, collaboration, problem-solving skills, learning autonomy, and perceived challenges during project activities. These themes represent the most frequently identified patterns from the collected qualitative data. The summary of the findings is presented in Table 1.

Table 1. Students' Learning Experiences in Project-Based Learning in Science Classes

| Learning Experience Dimension | Indicators Observed | Students' Responses | Learning Implications |
|---|---|---|---|
| **Student Engagement** | Active participation in project activities, discussion, and experimentation | Students showed high enthusiasm and were more involved in learning tasks compared to traditional lessons | Increased motivation and active participation in science learning |
| **Collaboration** | Group discussion, shared decision-making, and peer support during projects | Students frequently exchanged ideas and worked collaboratively to complete tasks | Improved teamwork and communication skills |
| **Problem-Solving Skills** | Identifying problems, designing solutions, and testing project outcomes | Students demonstrated the ability to analyze problems and explore creative solutions | Development of critical thinking and analytical abilities |
| **Learning Autonomy** | Self-directed learning, planning project steps, and managing time | Students showed greater responsibility for their learning process | Increased independence and self-regulated learning |
| **Learning Challenges** | Difficulties in managing tasks, time constraints, and uneven participation | Some students initially struggled with project planning and coordination | Need for teacher guidance and structured project management |

The results presented in Table 1 indicate that the implementation of Project-Based Learning significantly enriched students' learning experiences in science education. Students demonstrated higher levels of engagement and participation compared to traditional instructional approaches, suggesting that project-based activities can create a more interactive and motivating learning environment. The collaborative nature of PjBL also allowed students to exchange ideas, negotiate solutions, and support one another during the learning process, which contributed to the development of teamwork and communication skills. Furthermore, students showed improvements in problem-solving abilities as they were required to identify scientific problems and design solutions through project activities. Another important finding was the growth of learning autonomy, as students became more responsible for planning and managing their own learning tasks. However, the results also revealed several challenges, particularly related to time management and coordination within groups. These findings suggest that while Project-Based Learning can enhance students' learning experiences and promote active learning in science education, effective teacher facilitation and clear project structure remain essential to support successful implementation.

### 3.2. Discussion

The purpose of this study was to analyze students' learning experiences during the implementation of Project-Based Learning (PjBL) in science education. The findings presented in Table 1 indicate that students' learning experiences in PjBL were characterized by increased engagement, collaborative learning, the development of problem-solving abilities, greater learning autonomy, and several challenges related to project management. These results suggest that PjBL creates a learning environment where students are not only recipients of knowledge but also active participants in constructing scientific understanding. This transformation of the learning process reflects the fundamental principle of student-centered learning, which positions students as the main actors in the learning process while teachers function as facilitators guiding inquiry and exploration. In science education, such active participation is particularly important because scientific understanding is often developed through experimentation, observation, and collaborative problem solving rather than passive memorization of facts (Al-Qoyyim & Kurniawan, 2025).

One of the most prominent findings of this study is the increased level of student engagement during project-based science activities. Observational and interview data revealed that students demonstrated higher enthusiasm and participation when they were involved in authentic projects related to real-life scientific phenomena. Students reported that learning science through projects felt more interesting and less monotonous compared to traditional lecture-based instruction. These findings support previous research indicating that PjBL can transform science learning into an engaging and meaningful experience because students are encouraged to explore real problems and apply scientific concepts in practical contexts. When students perceive learning activities as relevant to their daily lives, they tend to become more motivated and actively involved in the learning process (Saputra et al., 2025).

The increased engagement observed in this study is also closely related to the contextual nature of project-based learning activities. In the PjBL approach, students often work on projects that require them to investigate real-world phenomena, such as environmental issues, biological processes, or physical experiments. These authentic learning contexts enable students to connect abstract scientific concepts with practical applications, which helps them develop deeper conceptual understanding. Previous studies have shown that contextual learning experiences in PjBL can significantly improve students' interest in science and make complex topics such as ecosystems or metamorphosis easier to understand. As a result, science learning becomes more meaningful because students can directly observe how scientific principles operate in real situations (Santhika & Rohmani, 2025).

Another important dimension of students' learning experiences identified in this study is collaborative learning. The results show that students frequently engaged in group discussions, shared ideas, and cooperatively solved problems during project activities. Collaboration allowed students to exchange different perspectives, negotiate solutions, and collectively construct knowledge. Such collaborative interactions are essential in science education because scientific inquiry often involves teamwork and the integration of diverse ideas. Previous research indicates that PjBL creates collaborative learning environments where students learn from each other while developing communication and teamwork skills.

These social interactions not only improve academic understanding but also strengthen interpersonal competencies that are essential for twenty-first century learning (Yuniati & Purwandari, 2025).

The collaborative dimension of PjBL also contributes to the development of students' sense of responsibility and shared ownership of learning tasks. During project activities, students were required to distribute responsibilities among group members, coordinate their work, and present their findings collectively. This process encouraged students to take accountability for their contributions while also supporting their peers in achieving common goals. Such experiences help students develop important social skills such as negotiation, leadership, and conflict resolution. These findings are consistent with previous studies showing that PjBL not only improves cognitive outcomes but also promotes social learning and collaborative competence among students (Nurhidayah et al., 2021).

The development of problem-solving skills was another significant aspect of students' learning experiences identified in this study. Students reported that working on projects required them to identify problems, design experimental procedures, collect data, and evaluate possible solutions. These processes stimulated critical thinking and analytical reasoning, which are essential components of scientific literacy. In contrast to traditional instruction where students often follow predetermined procedures, PjBL allows students to explore multiple pathways toward solving scientific problems. This open-ended learning structure encourages students to experiment, reflect, and refine their understanding through iterative inquiry processes (Chistyakov et al., 2023).

The findings also indicate that project-based learning can foster students' sense of agency and empowerment in the learning process. When students are given the opportunity to design and manage their own projects, they develop a stronger sense of ownership over their learning activities. This sense of agency can enhance motivation and confidence because students feel capable of addressing complex problems and producing meaningful outcomes. Several studies have demonstrated that project-based inquiry approaches can strengthen students' sense of empowerment and encourage them to view themselves as capable problem solvers who can contribute to addressing real-world challenges (Krupa et al., 2025).

In addition to enhancing engagement and problem-solving abilities, the implementation of PjBL in this study also promoted students' learning autonomy. Students were responsible for planning project steps, gathering information from various sources, conducting experiments, and presenting their findings. Such responsibilities require students to regulate their learning processes independently, which supports the development of self-directed learning skills. These findings align with previous research showing that PjBL encourages students to become more independent learners who actively manage their learning strategies and monitor their progress throughout the learning process (Al-Qoyyim & Kurniawan, 2025).

Learning autonomy developed through project-based activities is closely linked to the concept of self-regulated learning. When students engage in project planning, information searching, experimentation, and reflection, they practice regulating their cognitive and behavioral processes. This ability to self-regulate learning is particularly important in science education, where students must often interpret complex information and evaluate experimental results. Studies have shown that students who participate in PjBL environments tend to develop stronger self-regulated learning skills because they are continuously involved in planning, monitoring, and evaluating their learning activities (Chistyakov et al., 2023).

Despite the positive learning experiences identified in this study, several challenges were also observed during the implementation of PjBL. Some students reported difficulties related to time management, project planning, and coordination within their groups. These challenges are not unexpected because project-based learning requires students to manage multiple tasks simultaneously while collaborating with peers. For students who are accustomed to teacher-directed instruction, adapting to a more autonomous learning environment can initially be challenging. Such difficulties highlight the importance of providing adequate scaffolding and guidance during the early stages of PjBL implementation (Dhitareka et al., 2025).

Previous studies also indicate that the effectiveness of PjBL in enhancing motivation and engagement is influenced by several contextual factors, including the duration of project activities, teacher facilitation skills, and students' prior learning experiences. In some cases, short project durations or poorly structured activities may limit the potential benefits of PjBL, leading to mixed results in terms of student motivation. Therefore, the success of PjBL depends not only on the instructional model itself but also on the quality of its implementation in the classroom (Spires et al., 2022).

Another important finding of this study relates to the impact of students' learning experiences on science literacy and conceptual understanding. When students actively participate in project-based activities, they are more likely to develop deeper understanding of scientific concepts because they apply theoretical knowledge in practical situations. The process of designing experiments, collecting data, and interpreting results helps students build connections between abstract scientific principles and real-world phenomena. This experiential learning process plays a crucial role in developing scientific literacy, which involves the ability to apply scientific knowledge in solving everyday problems (Ambarwati et al., 2025).

Furthermore, the collaborative and inquiry-based nature of PjBL contributes to the development of twenty-first century skills such as critical thinking, creativity, problem solving, and teamwork. These competencies are increasingly recognized as essential outcomes of modern education because they prepare students to address complex challenges in rapidly changing societies. Research in STEM education consistently shows that project-based and inquiry-based learning environments provide effective opportunities for students to develop these competencies while simultaneously strengthening their conceptual understanding of scientific content (Wu et al., 2021).

In the context of elementary science education, PjBL has also been shown to improve students' learning outcomes and classroom participation. Students tend to become more active in asking questions, conducting experiments, and presenting their ideas when they are involved in project-based activities. These active learning experiences help create a dynamic classroom atmosphere where students feel comfortable expressing their ideas and exploring scientific concepts collaboratively. Consequently, PjBL can transform the science classroom into a more interactive and meaningful learning environment (Aprida & Mayarni, 2023).

The findings of this study also highlight the importance of examining students' learning experiences in order to fully understand the effectiveness of PjBL. Many previous studies on project-based learning primarily focus on academic achievement indicators such as test scores or conceptual understanding. While these indicators are valuable, they do not capture the subjective experiences that shape how students perceive and respond to learning activities. Investigating students' experiences provides deeper insights into the emotional, social, and cognitive dimensions of learning that influence educational outcomes (Wu et al., 2021).

By focusing on students' lived learning experiences, this study addresses an important gap in existing research on project-based science education. Understanding how students experience each stage of the project process from planning and experimentation to presentation can help educators design more effective learning environments. Such insights are particularly valuable for identifying factors that enhance or hinder students' engagement, motivation, and sense of agency during project-based activities (Krupa et al., 2025).

Overall, the findings of this study demonstrate that Project-Based Learning can create rich and meaningful learning experiences for students in science education. Through active engagement, collaboration, problem solving, and self-directed learning, students develop both conceptual understanding and essential competencies for modern education. However, successful implementation requires careful planning, teacher guidance, and supportive classroom environments that help students navigate the challenges of project-based learning. Therefore, understanding students' learning experiences provides valuable insights for improving the design and implementation of PjBL in science classrooms.

## 4. CONCLUSION

This study aimed to analyze students' learning experiences during the implementation of Project-Based Learning (PjBL) in science education. The findings indicate that PjBL creates meaningful and active learning experiences characterized by increased student engagement, collaborative interaction, the development of problem-solving abilities, and greater learning autonomy. Through project activities, students were able to connect scientific concepts with real-life contexts, participate actively in discussions and experimentation, and develop a sense of responsibility for their learning processes. These experiences also contributed to the development of important competencies such as critical thinking, teamwork, and scientific inquiry skills. Although several challenges were identified, particularly related to time management and group coordination, the overall findings demonstrate that Project-Based Learning provides a learning environment that supports deeper conceptual understanding and positive learning experiences in science education. Therefore, examining students' learning experiences offers valuable insights into how PjBL can enhance both cognitive and affective aspects of science learning.

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## REFERENCES

Al-Qoyyim, T., & Kurniawan, W. (2025). Project-Based Learning in science learning: A literature review. *Contextual Natural Science Education Journal*. https://doi.org/10.29303/cnsej.v3i1.1053

Ambarwati, N., Suyanti, R., Loh, A., Sembiring, B., Sofia, D., Tanjung, D., Sari, W., Wulan, D., & Sari, H. (2025). Innovate integration of guided inquiry learning (GIL) and project-based learning (PjBL) to enhance students' science literacy. *Primary: Jurnal Pendidikan Guru Sekolah Dasar*. https://doi.org/10.33578/jpfkip.v14i4.p569-583

Amimaruddin, D., & Rudita Idris, D. (2021). Exploring student nurses' learning experience in the clinical setting: A literature review. *International Journal of Nursing Education*. https://doi.org/10.37506/ijone.v14i1.17733

Aprida, H., & Mayarni, M. (2023). Efficiency of PjBL (Project Based Learning) model assisted by e-worksheet on student learning outcomes in science subjects. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v9i8.4372

Arnold, J. (2022). Prioritising students in assessment for learning: A scoping review of research on students' classroom experience. *Review of Education*. https://doi.org/10.1002/rev3.3366

Beltrán, N., Fernández, A., Blanco, D., Martín, J., & Zapico, P. (2025). Enhancing project-based learning: A handoff-structured model for balanced roles. *International Journal of Mechanical Engineering Education*. https://doi.org/10.1177/03064190251383880

Bhardwaj, V., Zhang, S., Tan, Y., & Pandey, V. (2025). Redefining learning: Student-centered strategies for academic and personal growth. *Frontiers in Education*. https://doi.org/10.3389/feduc.2025.1518602

Chistyakov, A., Zhdanov, S., Avdeeva, E., Dyadichenko, E., Kunitsyna, M., & Yagudina, R. (2023). Exploring the characteristics and effectiveness of project-based learning for science and STEAM education. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.29333/ejmste/13128

Closs, L., Mahat, M., & Imms, W. (2021). Learning environments' influence on students' learning experience in an Australian Faculty of Business and Economics. *Learning Environments Research, 25*, 271–285. https://doi.org/10.1007/s10984-021-09361-2

Dhitareka, P., Nuraeni, S., Winarno, N., Sriyati, S., & Supriyatin, T. (2025). Exploring the effectiveness of project-based learning on students' motivation in science: An action research study. *Jurnal Kajian Pendidikan IPA*. https://doi.org/10.52434/jkpi.v5i1.42597

Jiang, C., & Pang, Y. (2023). Enhancing design thinking in engineering students with project-based learning. *Computer Applications in Engineering Education, 31*, 814–830. https://doi.org/10.1002/cae.22608

Karcher, E., & Ragland, E. (2025). Influence of group inquiry-based learning experimentation on student interest, experience, and motivation in an introductory animal agriculture course. *NACTA Journal*. https://doi.org/10.56103/nactaj.v69i1.202

Krajcik, J., Schneider, B., Miller, E., Chen, I., Bradford, L., Baker, Q., Bartz, K., Miller, C., Li, T., Codere, S., & Peek-Brown, D. (2022). Assessing the effect of project-based learning on science learning in elementary schools. *American Educational Research Journal, 60*, 70–102. https://doi.org/10.3102/00028312221129247

Krupa, E., Borden, M., Spires, H., & Himes, M. (2025). Interdisciplinary project based-inquiry: Empowering students to solve global problems. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.29333/ejmste/16396

Mutanga, M. (2024). Students' perspectives and experiences in project-based learning: A qualitative study. *Trends in Higher Education*. https://doi.org/10.3390/higheredu3040052

Mubarok, A., Nurazizah, Z., Herawan, E., & Putri, D. (2025). Deep learning with project-based learning (PjBL) model for student creativity. *Pedagogia: Jurnal Pendidikan*. https://doi.org/10.21070/pedagogia.v14i2.1957

Napitupulu, B. (2025). Student experience quality in higher education: Trends, theoretical foundations, and directions for future research. *JOCE-IP*. https://doi.org/10.58217/joceip.v19i2.99

Nurhidayah, I., Wibowo, F., & Astra, I. (2021). Project based learning (PjBL) learning model in science learning: Literature review. *Journal of Physics: Conference Series, 2019*. https://doi.org/10.1088/1742-6596/2019/1/012043

Rehman, N., Huang, X., Mahmood, A., AlGerafi, M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-century skills and student engagement in the math classroom. *Heliyon, 10*. https://doi.org/10.1016/j.heliyon.2024.e39988

Santhika, R., & Rohmani, R. (2025). Transformation of elementary science learning with the project-based learning model. *International Journal of Elementary Education*. https://doi.org/10.23887/ijee.v9i1.92889

Saputra, J., Sari, S., & Kasmini, L. (2025). Student activity in project-based learning (PjBL) science learning to improve student learning outcomes of Ranto Panyang I State Elementary School. *JISAE: Journal of Indonesian Student Assessment and Evaluation*. https://doi.org/10.21009/jisae.v11i1.53085

Sarsale, J., & Langub, M. (2023). Effects of student-centered learning approaches towards interest in science. *Journal of Research, Policy & Practice of Teachers & Teacher Education*. https://doi.org/10.37134/jrpptte.vol13.2.5.2023

Santos, B. (2025). Reimagining science education through student-led dynamics. *Psychology and Education: A Multidisciplinary Journal*. https://doi.org/10.70838/pemj.440805

Spires, H., Himes, M., & Krupa, E. (2022). Supporting students' science content knowledge and motivation through project-based inquiry (PBI) global in a cross-school collaboration. *Education Sciences*. https://doi.org/10.3390/educsci12060412

Subiyantoro, S. (2024). Evaluating students' experiences with project-based learning in online educational contexts. *EDUKASIA: Jurnal Pendidikan dan Pembelajaran*. https://doi.org/10.62775/edukasia.v5i1.812

Sun, D., & Ashari, Z. (2024). Project-based learning in early science education: A systematic review. *International Journal of Academic Research in Progressive Education and Development*. https://doi.org/10.6007/ijarped/v13-i2/21365

Tang, K., McLure, F., Williams, J., & Donnelly, C. (2024). Investigating the role of self-selected STEM projects in fostering student autonomy and self-directed learning. *The Australian Educational Researcher, 51*, 2355–2379. https://doi.org/10.1007/s13384-024-00696-2

Wiladati, S., & Fitriyeni, F. (2025). The implementation of the project-based learning (PjBL) model to improve learning outcomes and motivation in the metamorphosis topic of natural science for third-grade elementary school students. *TOFEDU: The Future of Education Journal*. https://doi.org/10.61445/tofedu.v4i6.817

Wu, X., Sandoval, C., Knight, S., Jaime, X., Macik, M., & Schielack, J. (2021). Web-based authentic inquiry experiences in large introductory classes consistently associated with significant learning gains for all students. *International Journal of STEM Education, 8*. https://doi.org/10.1186/s40594-021-00290-3

Yuniati, Y., & Purwandari, R. (2025). Implementation of project-based learning (PjBL) model in science subject for grade V at SDN 2 Sered on ecosystem material. *Proceedings Series on Social Sciences & Humanities*. https://doi.org/10.30595/pssh.v25i.1675