World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Learning the human respiratory system through project-based learning: A quasi-experimental study

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World Journal of Advanced Research and Reviews, 2026, 30(03), 2218–2227

Publication history: Received on 01 May 2026; revised on 24 June 2026; accepted on 28 June 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.3.1675

Abstract

Science education in elementary schools aims to develop students' conceptual understanding through meaningful learning experiences. However, the topic of the human respiratory system remains one of the most challenging science topics because students often experience misconceptions in understanding the relationship between the structure and function of respiratory organs as well as the process of gas exchange when the material is delivered solely through verbal explanations. As a result, teacher-centered instruction is often insufficient to support students in developing a comprehensive scientific understanding. Therefore, an instructional approach that actively engages students in constructing their own knowledge is needed. This study aimed to examine the effect of Project-Based Learning (PjBL) on science learning outcomes in the human respiratory system. The study employed a quantitative approach using a quasi-experimental method with a nonequivalent control group design. The sample consisted of 40 students, who were assigned to an experimental group and a control group. The findings revealed that the implementation of PjBL had a significant positive effect on science learning outcomes. Project-based learning enhanced students' understanding of the subject matter by actively engaging them in inquiry, discussion, collaboration, product development, and project presentation, making the learning process more interactive and meaningful. Therefore, PjBL can be considered an effective instructional model for improving learning outcomes while helping to reduce misconceptions related to the human respiratory system. Future research is recommended to apply PjBL to other science topics and to investigate its effects on students' scientific literacy, critical thinking skills, and 21st-century competencies.

Keywords: Project-Based Learning; Learning Outcomes; Science Education; Human Respiratory System

1. Introduction

Education serves as a strategic means of developing individual potential, promoting economic growth, and improving the quality of social life. Therefore, education plays a fundamental role in preparing individuals to adapt and compete in an increasingly dynamic society. In this context, elementary school represents a critical stage of development, as it provides the foundation for children's physical, cognitive, emotional, and social development, all of which influence their future growth and learning (Singh, 2016). Science education at the elementary level plays a vital role in helping students understand themselves, the natural environment, and the society in which they live. Science learning should not be limited to memorizing concepts; rather, it should encourage students to observe, question, investigate, and relate scientific knowledge to their everyday experiences. Consequently, science instruction should be designed to provide meaningful learning experiences that actively engage students in constructing their own understanding. The framework of 21st-century skills identifies life and career skills, learning and innovation skills, and information, media, and technology skills as essential competencies that students are expected to acquire. Among these competencies, problem-

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solving is considered one of the most important components of learning and innovation skills. In science education, problem-solving enables students to integrate scientific concepts through active engagement in the process of identifying and solving problems, making learning more meaningful than passive knowledge acquisition (Gallagher, 1997; Wu et al., 2019). In Indonesia, the government has continuously implemented various initiatives to improve the quality of education across all levels, from elementary schools to higher education institutions. One of the major reforms is the implementation of the 2013 Curriculum, which emphasizes a thematic scientific approach to learning (Susanta et al., 2023). One of the primary objectives of science education is not only to promote conceptual mastery but also to develop students' knowledge, skills, and competencies appropriate to their developmental stages. Science learning should therefore equip students with the ability to solve problems encountered in everyday life through the integration of scientific knowledge and practical skills. To achieve these objectives, learning environments should provide rich learning experiences and contextualized instructional materials that enable students to apply scientific concepts to real-world situations. In this regard, socioscientific issues have become an integral component of science education because science concepts are closely connected to contemporary phenomena and real-life challenges encountered in everyday life (Şaşmaz et al., 2023).

One of the core topics in elementary science education is the human respiratory system. This topic is closely related to students' daily lives because it is directly associated with breathing, maintaining good health, and developing healthy habits to protect the respiratory organs. However, several concepts within this topic remain difficult for students to understand when they are presented solely through verbal explanations. These include the mechanisms of inhalation and exhalation, lung function, the role of the diaphragm, and the process of oxygen and carbon dioxide exchange. Therefore, instruction on the human respiratory system should incorporate learning activities that enable students to develop a concrete understanding of these concepts rather than merely memorizing scientific terminology (Srikandi et al., 2025). Children aged 4–7 years already possess prior knowledge of internal body organs, particularly those involved in eating and breathing, although this knowledge remains relatively simple and is not yet fully aligned with scientific concepts. Most children are able to identify the stomach as the organ responsible for digestion and the lungs as the organs involved in respiration, and they can apply this knowledge to familiar animals such as dogs, ducks, and fish. Their understanding of the digestive system develops more rapidly than their understanding of the respiratory system. As children grow older, their mental representations of the digestive system become increasingly sophisticated, enabling them to recognize the relationships among the mouth, stomach, and intestines. In contrast, misconceptions about the respiratory system remain common. For example, many children initially believe that inhaled air enters the stomach or the heart before gradually developing a more accurate understanding of lung function. A three-year longitudinal study further revealed that children's conceptual understanding progressed from simplistic representations toward more scientifically accurate explanations. However, this development was gradual and not always linear, as some misconceptions persisted despite increasing age. Overall, these findings indicate that young children are not "blank slates" when learning biology. Instead, they enter the classroom with pre-existing mental models of the structure and function of body organs that have been developed through everyday experiences. Therefore, teachers should identify students' prior knowledge before instruction begins and design learning activities that explicitly address misconceptions while gradually guiding students toward scientifically accurate understanding. These findings provide an important foundation for designing effective elementary science instruction, particularly in topics related to the digestive and respiratory systems (Garcia-Barros et al., 2011).

These challenges indicate that teachers need to select instructional models that are aligned with the characteristics of the subject matter. The human respiratory system can be understood more effectively when students are provided with opportunities to observe, create, explain, and present the concepts they have learned. One instructional approach that addresses these needs is Project-Based Learning (PjBL). PjBL is a student-centered instructional model that encourages learners to develop problem-solving skills while engaging in meaningful learning experiences through project-based activities. Within this approach, students are encouraged to construct knowledge independently, process information, complete authentic tasks, and produce tangible products that demonstrate their learning (Ibragimov, 2021). In addition, PjBL provides opportunities for students to express their ideas and creativity through process-oriented learning activities. As a process-oriented instructional approach, PjBL requires an interactive and collaborative learning environment (Li et al., 2020). Throughout project implementation, students may work individually or collaboratively to complete authentic and contextualized projects that often integrate knowledge from multiple disciplines to solve real-world problems (Belayneh, 2021). Students are also given considerable autonomy in determining the strategies, procedures, and activities required to complete their projects. Through these learning experiences, students become more motivated and develop a deeper understanding of scientific concepts because knowledge is constructed through direct experience and active engagement in the learning process (Chistyakov et al., 2023). Previous studies have consistently demonstrated the positive effects of PjBL on science learning outcomes in elementary education. Zhang (2023) reported that PjBL is more effective than conventional instruction in improving students' science learning outcomes. In addition to enhancing academic achievement, PjBL also contributes to the development of students' affective attributes and higher-order thinking skills, with improvements in academic performance representing its most significant educational outcome (Cai et al., 2023).

Project-Based Learning (PjBL) is a student-centered instructional approach designed to foster problem-solving, critical thinking, collaboration, and a wide range of cognitive and affective skills that support students' intellectual development and creativity (Lam et al., 2010; Greenier & Greenier, 2020). By actively engaging students in authentic projects, PjBL facilitates the development of essential 21st-century competencies, including critical thinking, communication, collaboration, and creativity (Marini et al., 2025). Despite its well-documented advantages in enhancing the quality of teaching and learning, the successful implementation of PjBL largely depends on teachers, who play a central role in facilitating the learning process (Lam et al., 2008). Previous research has shown that most elementary school teachers in China hold positive perceptions of Project-Based Learning (PjBL). However, the extent to which teachers embrace and implement PjBL is influenced by several factors, including their educational background, teaching experience, and subject specialization (Cai et al., 2023). Teachers' attitudes toward instructional innovations are critical determinants of successful classroom implementation (Stains & Vickrey, 2017). Teachers with positive attitudes and strong intrinsic motivation toward PjBL are more likely to create supportive learning environments in which students receive effective guidance throughout the learning process. Conversely, negative attitudes or anxiety toward either the subject matter or the instructional approach may adversely affect students' perceptions of learning and reduce their motivation (Miller & Krajcik, 2019). Therefore, a comprehensive understanding of teachers' attitudes toward PjBL is essential for improving the quality of its implementation and for developing more effective strategies to support its adoption across diverse educational contexts. Based on these considerations, this study aimed to examine the effect of Project-Based Learning on students' science learning outcomes in the topic of the human respiratory system.

2. Methods

This study employed a quantitative approach using a quasi-experimental design, specifically the nonequivalent control group design. According to Hong & Vegas (2010), the nonequivalent control group design is a type of quasi-experimental design involving two groups: an experimental group that receives the treatment and a control group that does not. Unlike a true experimental design, participants are not randomly assigned to groups. Instead, existing classes or intact groups are used, making this design particularly suitable for educational research where random assignment is often impractical. Because randomization is not employed, the experimental and control groups cannot be assumed to be equivalent at baseline. Consequently, the groups may differ in several initial characteristics, such as academic ability, learning motivation, cognitive ability, prior learning experiences, and socioeconomic background, all of which may influence the study outcomes. Therefore, researchers using this design should make every effort to minimize the influence of potential confounding variables in order to improve the validity of the findings and ensure that any observed differences can be more accurately attributed to the treatment. Although the nonequivalent control group design has certain limitations compared with a true experimental design, it remains one of the most widely used quasi-experimental designs in educational research. This design enables researchers to evaluate the effectiveness of instructional models, teaching methods, or educational media under authentic classroom conditions without disrupting the regular teaching and learning process

Table 1 Research Design

Group	**Pretest**	**Treatment**	**Post-test**
Experimental	O_1	X	O_2
Control	O_3	–	O_4

Note: O_1 = Pretest of the experimental group; O_2 = Posttest of the experimental group; O_3 = Pretest of the control group; O_4 = Post-test of the control group; X = Instruction using the PjBL model; (-) = Conventional instruction

The study was conducted at SD Negeri 1 Passo, Baguala District, Ambon City, Indonesia. The study population consisted of all fifth-grade students enrolled in two existing classes. The sample was selected using a total sampling technique, comprising 40 students: 20 students were assigned to the experimental group and 20 students to the control group. The experimental group received instruction using the PjBL model, whereas the control group was taught using conventional instructional methods. Data were collected using pretests and posttests to measure students' science learning outcomes. The research instrument consisted of 15 multiple-choice questions and 5 essay questions covering the topic of the human respiratory system. The research procedure included four stages: administering the pretest, implementing the instructional intervention, administering the posttest, and analyzing the learning outcomes. Data analysis was performed using IBM SPSS Statistics version 25. The normality of the data was assessed using the Shapiro–

Wilk test. The study hypothesis was tested using an Independent Samples t-test with a significance level of 0.05, while improvements in students' learning outcomes were evaluated using the normalized gain (N-Gain) index.

Rumus N-Gain yang digunakan adalah sebagai berikut:

$$\text{N-Gain}=\frac{\text{Posttest Score}-\text{Pretest Score}}{\text{Maximum Possible Score}-\text{Pretest Score}}$$

The interpretation of *N*-Gain values followed the classification proposed by Hake (1998): low (*N*-Gain < 0.30), moderate (0.30 ≤ *N*-Gain < 0.70), and high (*N*-Gain ≥ 0.70)

3. Results and Discussion

Data on students' science learning outcomes were collected through pretests and posttests administered to both the control and experimental groups. The pretest was conducted prior to the instructional intervention to assess students' baseline knowledge, whereas the posttest was administered after the completion of the learning activities. The experimental group received instruction using the PjBL model, while the control group was taught using conventional instructional methods.

Table 2 Descriptive Statistics of Students' Science Learning Outcomes

Group	N	Mean Pretest	Mean Posttest	Minimum Posttest Score	Maximum Posttest Score	Posttest Score Posttest Standard Deviation
Control	20	51.51	72.99	44.50	90.83	12.02
Experimental	20	47.91	85.52	63.00	100	11.92

As presented in Table 2**,** the two groups exhibited relatively similar baseline achievement prior to the intervention. The control group obtained a mean pretest score of 51.51**,** while the experimental group achieved a mean pretest score of 47.91, indicating comparable initial levels of understanding. Following the instructional intervention, the experimental group demonstrated a substantial improvement, with the mean posttest score increasing to 85.52**,** compared with 72.99 in the control group. These findings indicate that students who were taught using the PjBL model achieved higher science learning outcomes than those who received conventional instruction. The higher posttest performance of the experimental group suggests that PjBL provided a more effective learning environment for facilitating students' understanding of the human respiratory system.

Before hypothesis testing, the data were assessed for normality. The Shapiro–Wilk test was employed because each group consisted of fewer than 50 participants. Data were considered normally distributed when the significance value exceeded 0.05.

Table 3 Results of the Shapiro–Wilk Normality Test

Data	Statistic	*df*	*p*-value	Interpretation
Control pretest	0.921	20	0.102	Normal
Control posttest	0.964	20	0.626	Normal
Experimental pretest	0.956	20	0.461	Normal
Experimental posttest	0.907	20	0.057	Normal

As shown in Table 3, all datasets produced significance values greater than 0.05, indicating that the assumption of normality was satisfied. The significance values were 0.102 for the control-group pretest, 0.626 for the control-group posttest, 0.461 for the experimental-group pretest, and 0.057 for the experimental-group posttest. Therefore, the learning outcome data for both groups were normally distributed, allowing subsequent analyses to be conducted using parametric statistical procedures.

Homogeneity of variance was then examined to determine whether the posttest variances of the control and experimental groups were equivalent. The Levene's test yielded a significance value of 0.474, which exceeded the threshold of 0.05, indicating that the assumption of homogeneity of variance was met. Consequently, the results reported under the equal variances assumed condition of the Independent Samples *t*-test were used for hypothesis testing.

Table 4 Results of the Independent Samples *t*-Test

Levene's *p*-value	*t*	*df*	*p* (2-tailed)	Mean Difference	Lower	Upper
0.474	-3.311	38	0.002	-12.53	-20.20	-4.87

As presented in Table 4, the Independent Samples *t*-test yielded a two-tailed significance value of 0.002, which is below the significance level of 0.05. Therefore, the null hypothesis was rejected, indicating a statistically significant difference in science learning outcomes between students who were taught using the PjBL model and those who received conventional instruction. The mean difference of −12.53 reflects the order of group comparison used in the SPSS output rather than a decline in student performance. Descriptively, the experimental group achieved a substantially higher mean posttest score than the control group, demonstrating the greater effectiveness of PjBL in improving students' understanding of the human respiratory system.

Learning improvement was further evaluated using the normalized gain (*N*-Gain) index, which measures the extent of students' learning progress after the instructional intervention. To present the findings more concisely and in accordance with the conventions of scientific journal articles, individual *N*-Gain scores are not reported; instead, the results are summarized using the mean *N*-Gain, minimum and maximum values, percentage gain, and performance category.

Table 5 Summary of *N*-Gain Results

Group	*N*	Mean *N*-Gain	Minimum	Maximum	Percentage	Category
Control	20	0.44	0.00%	81.35%	43.66%	Moderate
Experimental	20	0.70	20.09%	100.00%	70.33%	High

As shown in Table 5, the control group achieved a mean N-Gain of 0.44 (43.66%), which falls within the moderate category. In contrast, the experimental group obtained a mean N-Gain of 0.70 (70.33%), which is classified as high. These findings indicate that the improvement in students' science learning outcomes was substantially greater in the experimental group than in the control group. In other words, PjBL not only resulted in higher posttest scores but also produced greater learning gains than conventional instruction.

The significant differences in learning outcomes between the experimental and control groups indicate that PjBL provides a more effective learning experience than conventional instruction. In the experimental group, students were not merely passive recipients of information but actively participated in searching for information, engaging in discussions, developing project products, and presenting their work. These learning activities encouraged greater interaction with the subject matter, enabling students to understand the human respiratory system not simply as a collection of facts to be memorized but as a series of interconnected biological processes that could be observed, explained, and applied. The human respiratory system is a science topic that requires concrete learning experiences to facilitate meaningful understanding. Students need to comprehend the relationships among the respiratory organs, the mechanisms of inhalation and exhalation, and the physiological functions of each component of the respiratory system. This finding is consistent with the study by Utami et al. (2023), which reported that the implementation of PjBL in teaching the human respiratory system significantly improved elementary students' science learning outcomes. Similarly, Tupan et al. (2024) integrated the human respiratory system into PjBL through the use of project-based student worksheets, demonstrating that this topic is particularly well suited to instructional approaches that actively engage students in the learning process. Collectively, these findings reinforce the effectiveness of PjBL as an instructional strategy for teaching the human respiratory system in elementary science education.

The findings of the present study are consistent with those reported in previous experimental research. Li et al. (2020) concluded that teacher support in developing students' literacy skills plays a crucial role in enhancing their ability to construct scientific models in PjBL science classrooms. Such support includes guiding students to read and interpret multiple learning resources, write scientific explanations, engage in collaborative discussions, interpret visual and textual information, and communicate their ideas through both oral and visual representations. These instructional practices enable students to develop a deeper understanding of scientific concepts, connect evidence with scientific reasoning, and construct scientific models that accurately explain natural phenomena. Similarly, Severance et al. (2025) reported that elementary science learning becomes more meaningful when PjBL is integrated with making (hands-on creation and design activities) and computing (computational thinking and programming). The integration of these approaches enhances student engagement, promotes learner agency, fosters STEM identity, supports equitable and inclusive learning environments, and enables students to achieve science learning objectives by applying scientific knowledge to explain phenomena and solve authentic real-world problems. Likewise, Suryanti et al. (2021) demonstrated that integrating the STEAM approach with PjBL significantly improved students' scientific literacy compared with traditional instruction. Students in the experimental group achieved significantly higher posttest scores than those in the control group, indicating that the STEAM–PjBL approach provided a more effective learning experience. This integrated approach not only strengthened students' understanding of scientific concepts but also enhanced their ability to apply scientific knowledge in real-life contexts and to develop scientific literacy more comprehensively.

The superior learning outcomes observed in the experimental group can be attributed to the fundamental characteristics of PjBL, which positions students as active participants in the learning process. PjBL requires students to solve problems, make decisions, collaborate with peers, and produce authentic learning products (Wijnia et al., 2024). Miller et al. (2025) reported that PjBL enhances elementary students' cognitive flexibility, which significantly contributes to improvements in science achievement and scientific literacy. Accordingly, science instruction should be designed to promote collaboration, engage students in solving authentic problems, and provide opportunities to explore multiple ideas and solutions. Such learning experiences enable students to develop adaptive thinking, critical thinking, and creativity, all of which are essential for addressing both academic and real-world challenges. Pongkitwitoon (2017) further demonstrated that project-based learning effectively develops a broad range of 21st-century competencies, including creativity and innovation, critical thinking and problem-solving, communication and collaboration, digital citizenship, information literacy, and technological literacy. In addition to fostering these competencies, PjBL promotes positive learning behaviors by encouraging active participation, collaboration, enjoyable learning experiences, and greater motivation through engagement in authentic, project-oriented tasks. These findings suggest that PjBL is an effective instructional approach for preparing learners to meet the demands of 21st-century education. Furthermore, Miller et al. (2021) found that the implementation of PjBL increases students' active participation during classroom learning, while Novalia et al. (2025) reported that PjBL effectively promotes critical thinking among elementary school students. In the present study, students in the experimental group were required to understand the functions of the respiratory organs, identify the relationships among these organs, and explain the respiratory process through the products they developed. This learning process encouraged students not only to retain scientific knowledge but also to apply their understanding in completing authentic project tasks, thereby strengthening both their learning outcomes and conceptual application.

From the perspective of the learning process, PjBL also provides students with more meaningful learning experiences. Elisabet et al. (2019) reported that PjBL significantly improved both learning motivation and science achievement among sixth-grade students in China. Similarly, Natty et al. (2023) found that PjBL enhanced elementary students' creativity and science learning outcomes, while Leasa et al. (2023) demonstrated that PjBL effectively promoted students' creative thinking skills and improved their science achievement. These findings are consistent with the learning experiences observed in the experimental group of the present study, where students were actively engaged in learning activities rather than passively listening to teacher explanations. Such active participation enabled students to construct knowledge more meaningfully through exploration, collaboration, and hands-on learning. Further evidence supporting the effectiveness of PjBL has been reported across different educational contexts. Mursid et al. (2022) concluded that the implementation of Blended Project-Based Learning significantly improved university students' learning outcomes in an engineering drawing course, particularly in topics related to American and European orthographic projection systems. Students who learned through Blended PjBL achieved higher academic performance than those who participated in conventional blended learning. The effectiveness of this approach was even greater among students with strong creative thinking abilities, as they demonstrated superior collaboration, problem-solving, and project development skills. Accordingly, the authors recommended that Blended PjBL should be accompanied by instructional strategies that foster creative thinking in order to maximize learning outcomes. They also suggested extending the implementation of Blended PjBL to other engineering courses as an effective strategy for developing 21st-century competencies. Gabuardi (2021) further emphasized that PjBL differs fundamentally from traditional instructional approaches. In PjBL, students are challenged with open-ended problems that require them to acquire new knowledge while simultaneously developing a wide range of cognitive and practical skills. The approach provides continuous opportunities for feedback, reflection, and revision, allowing students to refine their work throughout the learning process. Moreover, students typically work collaboratively in teams and are expected to communicate effectively with instructors, peers, and broader audiences through oral, written, and visual forms of communication. These characteristics create an authentic learning environment in which students actively construct knowledge while developing essential interpersonal and professional competencies. Similarly, Marnewick (2023) concluded that implementing PjBL within agile project management education provides students with authentic and highly effective learning experiences. Through project-based activities, students not only produced tangible project artifacts but also developed competencies that are highly valued in professional practice, including critical thinking, problem-solving, communication, collaboration, time management, project management, technical expertise, and leadership. Furthermore, the iterative nature of agile methodologies was found to complement the principles of PjBL by facilitating continuous feedback, reflection, and product improvement throughout the learning process. The study also emphasized that the success of PjBL depends on instructional designs that faithfully implement the core principles of project-based learning, with instructors serving primarily as facilitators who provide ongoing guidance, support, and constructive feedback. Consequently, PjBL was recommended as an effective instructional approach not only for project management education but also for information systems and other applied disciplines because it successfully bridges theoretical knowledge with practical application while preparing students for the demands of the modern workplace.

The implementation of PjBL in the present study also highlights the crucial role of teachers as facilitators who guide and support students throughout the learning process. Musa et al. (2011) concluded that PjBL is an effective instructional approach for developing the competencies required in the workplace through meaningful learning experiences. Their study demonstrated that PjBL equips students with essential skills, including teamwork, decision-making, conflict management, communication, collaboration, planning, and organizational skills. Active engagement in project activities also enhances students' self-confidence, independence, critical thinking, and productivity in generating and discussing ideas. These findings suggest that PjBL effectively prepares learners to meet the demands of 21st-century competencies while addressing the skills expected by the modern workforce. Similarly, Al-Busaidi & Al-Seyabi (2021) reported that PjBL is an effective pedagogical approach for supporting the professional development of pre-service teachers. Through authentic, project-based learning experiences, students gained a deeper understanding of curriculum design concepts that had previously been perceived as abstract. The implementation of PjBL also strengthened a range of academic and professional competencies, including critical thinking, problem-solving, teamwork, time management, report writing, and the ability to connect theoretical knowledge with practical application. Although students encountered challenges in areas such as needs analysis, formulating learning objectives, and project management, they expressed highly positive perceptions of the overall learning experience. Consequently, the authors recommended PjBL as an effective instructional strategy in teacher education programs, emphasizing that successful implementation requires adequate guidance and continuous support from instructors throughout the learning process. Further evidence was provided by Awamleh (2024), who concluded that electronic Project-Based Learning (e-PBL) effectively enhances university students' academic achievement, learning motivation, and positive attitudes through technology-supported collaborative learning. Although successful implementation depends on sufficient institutional resources, instructor competence, and technological infrastructure, e-PBL was recommended as an innovative instructional strategy for fostering critical thinking, collaboration, and digital competence in higher education. Collectively, these studies reinforce the importance of the teacher's role not merely as a transmitter of knowledge but as a facilitator who provides continuous guidance, constructive feedback, and learning support, enabling students to maximize the benefits of project-based learning.

4. Conclusion

This study demonstrates that PjBL is an effective instructional approach for improving science learning outcomes, particularly in teaching the human respiratory system at the elementary school level. Through project-based activities, students actively participated in every stage of the learning process, including identifying problems, gathering and analyzing information, collaborating with peers, designing and producing project artifacts, and presenting their findings. Such active engagement enabled students to move beyond passive knowledge acquisition and instead construct their own understanding through authentic, contextual, and collaborative learning experiences. As a result, students developed a deeper and more meaningful understanding of the concepts related to the human respiratory system than those who learned through conventional teacher-centered instruction. Beyond improving conceptual understanding and academic achievement, the implementation of PjBL also fostered the development of essential 21st-century competencies, including critical thinking, creativity, communication, collaboration, and problem-solving skills. Throughout the project activities, students worked collaboratively, exchanged ideas, made decisions, and applied scientific concepts to explain real-world phenomena. These learning experiences not only strengthened students' academic performance but also promoted responsibility, independence, and active engagement in the learning process. The findings of this study are consistent with previous research demonstrating that PjBL creates more meaningful, interactive, and student-centered learning environments. Therefore, PjBL should be considered a valuable instructional strategy for elementary science education, particularly for topics that require conceptual understanding and higher-order thinking skills, such as the human respiratory system. When systematically implemented and supported by teachers acting as learning facilitators, PjBL has considerable potential to enhance both the quality of classroom instruction and students' learning outcomes while equipping learners with the competencies required to succeed in the challenges of the 21st century.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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