



Project-based science learning for enhancing students' self-awareness and environmental responsibility in junior high school education

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Abstract

Background: In science education, fostering students' self-awareness and environmental responsibility is essential for developing sustainable character and ecological consciousness. However, many science learning practices still emphasize conceptual understanding and academic achievement rather than engaging students in authentic environmental problem-solving activities. Consequently, innovative instructional approaches are needed to encourage students' active participation and strengthen their environmental responsibility through meaningful learning experiences.

Aims: This study aimed to examine the effectiveness of Project-Based Learning (PjBL) in enhancing students' self-awareness and environmental responsibility at SMP Muhammadiyah 13 Surabaya.

Method: This study employed a quantitative quasi-experimental design using a pretest-posttest control group approach. The reliability of the research instrument was tested using Cronbach's Alpha, resulting in a coefficient of 0.90. The collected data met the assumptions of normality and homogeneity prior to hypothesis testing. Data analysis was conducted using paired sample t-tests and independent sample t-tests.

Results: The findings demonstrated that students in the experimental group showed significantly higher improvement than those in the control group, with a significance value of 0.000 ($p < 0.05$). The experimental group achieved a mean score difference of 6.373 points higher than the control group. Furthermore, the implementation of PjBL increased students' self-awareness by 0.51 points and environmental responsibility by 0.63 points.

Conclusion: Project-Based Learning effectively promotes students' reflective abilities and environmental responsibility in science education. The findings suggest that contextual project-based activities can support the development of environmentally conscious and socially responsible students in modern educational settings.

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INTRODUCTION

Adolescence represents an important developmental stage in which individuals begin to shape their personality, emotional maturity, social responsibility, and life skills needed to face future challenges. In the context of twenty-first-century education, schools are expected not only to facilitate students' academic achievement but also to foster character development and social awareness (Carvalho & Santos, 2021; González-Pérez & Ramírez-Montoya, 2022; González-Salamanca et al., 2020; Lavy, 2020; Rehman et al., 2023). Educational institutions therefore play a strategic role in preparing students to become responsible individuals who are capable of contributing positively to society and the environment (Aldawsari et al., 2025; Alsarayreh et al., 2024). Modern education increasingly emphasizes the importance of integrating cognitive, affective,

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and behavioral dimensions within the learning process (Alafnan, 2025; Mehrad et al., 2024). However, many students still demonstrate low levels of self-awareness, limited emotional regulation, and insufficient concern for environmental sustainability. These conditions are often associated with learning practices that continue to prioritize content mastery and examination performance rather than reflective and contextual learning experiences. As a result, opportunities for students to develop empathy, responsibility, and environmental awareness are frequently overlooked in classroom activities. This situation indicates the need for innovative educational approaches that are capable of integrating academic learning with character development and real-world environmental issues. Science education has considerable potential to become an effective medium for promoting environmental responsibility because it directly relates to students' daily experiences and surrounding environmental conditions. Therefore, science learning should be designed to encourage students to actively participate in meaningful learning activities that strengthen both reflective awareness and environmental responsibility.

The educational conditions at SMP Muhammadiyah 13 Surabaya reflect several challenges related to students' self-awareness and environmental responsibility. Preliminary observations revealed that many students still showed limited participation in maintaining environmental cleanliness and preserving the school environment. Several students were observed disposing of waste improperly and demonstrating low initiative in maintaining classroom cleanliness. In addition, classroom learning activities were still predominantly dominated by teacher-centered instructional approaches that provided limited opportunities for active participation and reflective engagement (Awacorach et al., 2021; Woods & Copur-Gencturk, 2024). Students were often positioned as passive recipients of information rather than active participants in problem-solving activities (Kanphukiew & Nuangchalerm, 2024). Interview findings also indicated that many students experienced difficulties in recognizing their personal strengths, understanding their emotions, and managing their behavior in real-life situations (Aryuwat et al., 2024; Ayalon et al., 2022; Chye et al., 2024). This condition demonstrates that students require learning experiences that are capable of connecting theoretical knowledge with authentic environmental and social problems. Contextual learning activities are therefore necessary to encourage students to become more reflective, responsible, and actively engaged in environmental preservation efforts. One instructional approach that has the potential to address these issues is Project-Based Learning because it emphasizes direct student involvement in authentic projects and collaborative problem-solving activities (Almulla, 2020; Hussein, 2021; Karan & Brown, 2022). Through project-oriented learning experiences, students are expected to develop stronger self-awareness while simultaneously strengthening their environmental responsibility. Consequently, implementing Project-Based Learning within science education may provide meaningful opportunities for students to develop sustainable character and environmentally responsible behavior.

Project-Based Learning is a student-centered instructional model that emphasizes inquiry, collaboration, contextual learning, and problem-solving through meaningful project activities. This learning model encourages students to actively construct knowledge through direct interaction with authentic situations and real-world environmental problems. In science education, Project-Based Learning allows students to integrate scientific concepts, practical experiences, and reflective thinking into a unified learning process (Haatainen & Aksela, 2021; Markula & Aksela, 2022). Students are not only required to understand theoretical concepts but are also encouraged to apply their knowledge in solving practical environmental issues. Such learning experiences contribute to the development of important life skills, including communication, collaboration, decision-making, and self-management abilities (Mahdy & Zaghoul, 2020; Petersson et al., 2022). Self-awareness within educational contexts refers to students' ability to recognize their emotions, values, strengths, and responsibilities during social and academic interactions (Geary & Xu, 2022). Meanwhile,

environmental responsibility refers to students' awareness and willingness to participate actively in preserving and protecting the surrounding environment. Previous studies have demonstrated that Project-Based Learning can improve students' critical thinking, creativity, collaborative skills, and environmental awareness (Chang et al., 2022a; Wibowo et al., 2024; Williamson, 2023). Nevertheless, many previous studies primarily focused on cognitive learning outcomes rather than examining reflective awareness and environmental responsibility simultaneously. Therefore, further investigation is needed to explore how Project-Based Learning in science education can contribute to the development of students' self-awareness and environmental responsibility through contextual environmental projects.

Although previous studies have demonstrated that Project-Based Learning (PjBL) effectively improves students' academic achievement, collaboration skills, critical thinking, and learning engagement, most studies primarily focus on cognitive and instructional outcomes rather than students' reflective and environmental character development (Guo et al., 2020; Mutanga, 2024; Zhang et al., 2024). Several studies have also examined environmental responsibility and pro-environmental behavior in educational contexts; however, these studies mainly emphasize environmental attitudes and sustainability practices without integrating reflective self-awareness within science learning activities (Komalasari et al., 2022; Nourmoradi et al., 2022; Yusliza et al., 2020). Meanwhile, research related to self-awareness development has largely been conducted within psychological, social-emotional, and personal development perspectives rather than within science education contexts (Carden et al., 2022; DeMink-Carthew et al., 2020; London et al., 2023). Furthermore, studies investigating responsibility education generally focus on social responsibility and contextual educational environments without specifically integrating environmental responsibility through project-based science learning (Coelho & Menezes, 2021; Manzano-Sánchez et al., 2021). Therefore, limited empirical research has simultaneously examined the integration of Project-Based Learning, self-awareness, and environmental responsibility within junior high school science education, particularly in Indonesian secondary school contexts. This study addresses this gap by investigating the effectiveness of Project-Based Science Learning in enhancing students' self-awareness and environmental responsibility through contextual environmental projects in science classrooms.

This study aims to analyze the effectiveness of Project-Based Learning in enhancing students' self-awareness and environmental responsibility in junior high school science education. The research specifically focuses on students at SMP Muhammadiyah 13 Surabaya as participants in contextual science learning activities. Through the implementation of project-based environmental activities, students are expected to become more reflective, responsible, and actively involved in environmental preservation efforts. The study also seeks to examine whether Project-Based Learning can provide more meaningful learning experiences compared to conventional instructional approaches. In this research, students participate in collaborative projects that require inquiry, problem-solving, communication, and environmental engagement. The implementation of contextual projects is expected to encourage students to recognize their personal roles and responsibilities within their social and environmental surroundings. This study additionally aims to provide empirical evidence regarding the role of Project-Based Learning in promoting reflective awareness and environmentally responsible behavior among adolescents. The findings are expected to contribute to the development of innovative science learning strategies that integrate academic achievement with character education and sustainability values. Furthermore, the study is intended to serve as a practical reference for teachers in designing science learning activities that are more student-centered, contextual, and environmentally oriented. Ultimately, this research seeks to strengthen the integration of self-awareness and environmental responsibility within science education to support sustainable character formation among junior high school students.

LITERATURE REVIEW

Project-Based Learning (PjBL) is widely recognized as one of the most effective student-centered instructional approaches in modern education. This learning model emphasizes active student participation through authentic projects that are closely related to real-life situations and contextual problems. In science education, PjBL encourages students to construct knowledge independently through inquiry, investigation, collaboration, and reflective learning processes (Markula & Aksela, 2022; Retno et al., 2025). The implementation of project-oriented activities allows students to integrate conceptual understanding with practical experiences in solving environmental and social problems (Chang et al., 2022a; Tseng & Wang, n.d.). PjBL also supports the development of higher-order thinking skills because students are required to analyze problems, design solutions, and evaluate learning outcomes systematically (Hujjatusnaini et al., 2022; Loyens et al., 2023; Setiawan et al., 2026). Through collaborative project activities, students develop communication skills, teamwork abilities, and responsibility toward collective learning goals. The constructivist perspective explains that meaningful learning occurs when students actively interact with their environment and build understanding from direct experiences (Do et al., 2023). Therefore, project-based instruction creates learning environments that are more engaging, relevant, and meaningful for students. In science classrooms, contextual projects can help students understand scientific concepts more deeply because learning is connected with everyday environmental issues. Consequently, Project-Based Learning is considered highly relevant for supporting both academic achievement and character development within science education.

Self-awareness is an important component of personal and social development that influences students' behavior, emotional regulation, and learning engagement. In educational contexts, self-awareness refers to students' ability to recognize their emotions, strengths, weaknesses, values, and responsibilities during academic and social interactions (Abdel Hadi & Gharaibeh, 2023; DeMink-Carthew et al., 2020). Students with strong self-awareness tend to demonstrate better emotional control, reflective thinking, and decision-making abilities in various situations (Abdel Hadi & Gharaibeh, 2023; Balconi et al., 2023). Self-awareness also contributes to students' capacity to understand their learning needs and identify strategies for improving academic performance (DeMink-Carthew et al., 2020; Sohail & Akram, 2025). In addition, reflective awareness enables students to evaluate their actions and consider the consequences of their behavior toward themselves and others. Educational approaches that encourage reflection and active participation are considered effective for promoting self-awareness development among adolescents. Learning experiences that involve collaboration, inquiry, and real-world problem-solving can stimulate students to recognize their personal roles and responsibilities more effectively (Agbi & Yuangsoi, 2022; Gillies, 2023). Science learning activities that integrate authentic environmental projects also provide opportunities for students to develop reflective thinking through direct interaction with environmental issues. The development of self-awareness during adolescence is particularly important because this stage represents a critical period for identity formation and emotional maturity. Therefore, educational practices should provide meaningful experiences that support students' reflective development and emotional awareness within the learning process.

Environmental responsibility has become an important objective in contemporary education because environmental problems increasingly require active participation from younger generations. Educational institutions are expected to cultivate environmentally responsible attitudes and behaviors that encourage students to participate in environmental preservation efforts (Aldawsari et al., 2025; Altassan, 2023; C. Chen et al., 2025). Environmental responsibility refers to individuals' awareness, commitment, and willingness to protect and sustain the natural environment through responsible actions and decision-making (Afsar et al., 2020; Luo et al., 2020; Patwary, 2023).

In science education, environmental responsibility can be developed through contextual learning activities that connect scientific knowledge with real environmental issues encountered in daily life (Ardoín & Heimlich, 2021; Baptista et al., 2025; Garzón-Díaz, 2021). Students who actively engage in environmental projects tend to develop stronger awareness of ecological sustainability and environmental ethics. Environmental education also encourages students to understand the consequences of human activities on environmental quality and sustainability (Uralovich et al., n.d.; Yeşilyurt et al., 2020). Learning experiences that involve direct environmental observation and problem-solving activities can strengthen students' emotional connection with their surrounding environment. Furthermore, collaborative environmental projects promote social responsibility because students work together to identify and solve environmental problems collectively. Integrating environmental responsibility into science education is essential because scientific literacy should not only focus on conceptual understanding but also encourage sustainable behavior and ecological awareness. Therefore, environmental responsibility should become an integral component of science learning activities in modern educational settings.

The integration of Project-Based Learning within science education provides opportunities for students to simultaneously develop cognitive competencies, reflective awareness, and environmental responsibility. Through project-oriented science learning, students become active participants in identifying environmental problems, conducting investigations, and designing practical solutions for real-life issues (Djordjevic et al., 2026; Rizki & Suprpto, 2024). Authentic project experiences encourage students to apply scientific concepts while reflecting on their personal roles and responsibilities toward environmental sustainability (Rahmawati et al., 2022). In addition, collaborative project activities create learning environments that support communication, social interaction, and shared responsibility among students. Reflective learning processes embedded in Project-Based Learning also enable students to evaluate their actions, learning experiences, and environmental behavior critically (Bramwell-Lalor et al., 2020; Miranda et al., 2020; O'Toole et al., 2026). Contextual environmental projects can strengthen students' understanding of the relationship between scientific knowledge and environmental preservation efforts. Several educational studies have indicated that project-based instruction positively influences students' engagement, motivation, and environmental awareness. Furthermore, students who participate in experiential learning activities tend to demonstrate greater responsibility and active involvement in environmental conservation practices. The combination of inquiry, collaboration, and reflection within Project-Based Learning therefore creates meaningful educational experiences that support sustainable character development. Consequently, integrating Project-Based Learning into science education is considered an effective strategy for fostering environmentally responsible and reflective students.

Despite the increasing implementation of Project-Based Learning in science education, several challenges remain in understanding its influence on students' reflective and environmental competencies. Many educational studies still predominantly focus on academic achievement, critical thinking, and collaborative skills rather than examining reflective awareness and environmental responsibility simultaneously. In addition, research exploring the relationship between self-awareness and environmental responsibility within project-based science learning remains relatively limited. Existing studies often investigate environmental education and reflective learning separately without integrating both dimensions into a single instructional framework. This condition creates a research gap regarding how contextual environmental projects can contribute to students' reflective awareness and environmentally responsible behavior at the same time. Junior high school students represent an important target group for this investigation because adolescence is a critical stage for developing identity, responsibility, and environmental consciousness. Furthermore, contextual environmental learning in secondary education settings remains underexplored,

particularly in Indonesian science classrooms. Understanding the role of Project-Based Learning in promoting both self-awareness and environmental responsibility may therefore contribute to the development of more holistic educational strategies. Such investigations are also important for strengthening the integration of character education and sustainability values within science learning. Therefore, further research is necessary to examine how Project-Based Science Learning can effectively support students' reflective development and environmental responsibility through authentic and contextual educational experiences.

METHOD

Research Design

This study employed a quantitative approach using a quasi-experimental research design with a pretest–posttest control group design. The quasi-experimental design was selected because the study aimed to examine the effectiveness of Project-Based Learning (PjBL) in enhancing students' self-awareness and environmental responsibility through science learning activities. In this research design, two groups were involved, namely an experimental group and a control group. The experimental group received learning treatment through the implementation of Project-Based Learning, while the control group was taught using conventional learning methods consisting of lectures and question-and-answer activities. Both groups completed pretests before the implementation of the learning intervention and posttests after the learning activities had been completed. The pretest was conducted to identify students' initial levels of self-awareness and environmental responsibility before treatment. Meanwhile, the posttest was administered to measure students' improvement after participating in the learning process. This research design enabled the researchers to objectively compare differences between the experimental and control groups after the intervention was implemented. Furthermore, the design minimized the influence of external variables by comparing changes that occurred before and after treatment in both groups. Therefore, the quasi-experimental pretest–posttest control group design was considered appropriate for investigating the effectiveness of Project-Based Learning in science education.

Table 1. Pretest–Posttest Control Group Research Design

Group	Pretest (O1)	Treatment (X)	Posttest (O2)
Experimental	Initial test of self-awareness and environmental care	Project-Based Learning (PjBL)	Final test of self-awareness and environmental care
Control	Initial test of self-awareness and environmental care	Conventional learning (lectures and question-and-answer)	Final test of self-awareness and environmental care

Participants

The population of this study consisted of all seventh-grade students at SMP Muhammadiyah 13 Surabaya during the 2025/2026 academic year. The sample involved students from Class VIIE and Class VIIF who participated as the experimental and control groups. A total of 65 students were involved in the study, with 34 students assigned to the experimental group and 31 students assigned to the control group. The participants were selected using purposive sampling based on preliminary observations conducted by the researchers and science teachers. Initial observations indicated that students' self-awareness and environmental responsibility were still relatively low during science learning activities. Many students demonstrated limited participation in maintaining classroom cleanliness and environmental preservation activities. In addition, students tended to show low reflective awareness and limited emotional regulation during classroom interactions. The selected classes also demonstrated relatively similar academic conditions and classroom learning characteristics before the intervention was conducted. Science teachers were involved in supporting the implementation of the Project-Based Learning activities during the research process. The

participants were considered suitable for this study because adolescence represents an important developmental stage for fostering reflective awareness, responsibility, and environmental consciousness. Therefore, the selected participants provided relevant data for examining the effectiveness of Project-Based Learning in improving students' self-awareness and environmental responsibility.

Instruments

The research instrument consisted of questionnaires designed to measure students' self-awareness and environmental responsibility. The questionnaires were developed using a four-point Likert scale to identify students' attitudes, reflective awareness, emotional regulation, and environmental care behavior. The self-awareness questionnaire included indicators related to emotional recognition, self-evaluation, emotional control, and understanding of personal strengths and weaknesses. Meanwhile, the environmental responsibility questionnaire measured students' awareness of environmental cleanliness, environmental preservation behavior, participation in environmental activities, and influence on others regarding environmental care. Each variable consisted of twelve statement items arranged systematically based on the developed indicators. The questionnaires were designed in positive statement forms to facilitate students' understanding during the response process. Before the primary data collection process, the instruments were validated through expert judgment involving experts in education, environmental education, character development, and measurement instruments. The validation process evaluated item relevance, clarity, appropriateness, and indicator representation within each instrument. Suggestions and feedback from experts were used to revise and improve the questionnaire items both technically and substantively. Reliability testing was conducted using Cronbach's Alpha, resulting in a reliability coefficient of 0.90, which indicated high internal consistency of the instruments. Data collection was conducted twice through pretests and posttests administered before and after the implementation of Project-Based Learning activities.

Table 2. Blueprint of Self-Awareness Questionnaire

Variables	Indicator	Amount of Items	Form of Measurement	Measurement Scale
Self-Awareness	Recognize personal emotions	3	Questionnaire	Likert Scale
	Recognize strengths and weaknesses	3	Questionnaire	Likert Scale
	Control emotions and behavior	3	Questionnaire	Likert Scale
	Evaluate personal actions	3	Questionnaire	Likert Scale
Total		12		

Table 3. Blueprint of Environmental Responsibility Questionnaire

Variables	Indicator	Amount of Items	Form of Measurement	Measurement Scale
Environmental Responsibility	Awareness of environmental cleanliness	3	Questionnaire	Likert Scale
	Environmentally responsible behavior	4	Questionnaire	Likert Scale
	Participation in environmental preservation	3	Questionnaire	Likert Scale
	Influencing others to care for the environment	2	Questionnaire	Likert Scale
Total		12		

Table 4. Self-Awareness Questionnaire Indicators

Indicator	Item Number	Statement
Recognize personal emotions	1-3	Ability to recognize emotions and feelings
Recognize strengths and weaknesses	4-6	Ability to recognize personal strengths and weaknesses

Control emotions and behavior	7-9	Ability to regulate emotions and behavior
Evaluate personal actions	10-12	Ability to evaluate personal experiences and actions

Table 5. Environmental Responsibility Questionnaire Indicators

Indicator	Item Number	Statement
Awareness of environmental cleanliness	13-15	Awareness of environmental cleanliness importance
Environmentally responsible behavior	16-19	Responsible environmental behavior
Participation in environmental preservation	20-22	Participation in environmental preservation activities
Influencing others	23-24	Encouraging others to care for the environment

Data Analysis

The collected data were analyzed quantitatively using descriptive and inferential statistical techniques. Descriptive statistics were conducted to determine the mean scores, minimum scores, maximum scores, and standard deviations of students' self-awareness and environmental responsibility. Before conducting inferential statistical analysis, the data were examined using validity and reliability tests. Content validity was analyzed using Aiken's V method involving expert evaluation to determine the appropriateness, clarity, and relevance of the instrument items. The Content Validity Ratio (CVR) and Content Validity Index (CVI) were calculated to ensure that the questionnaire items accurately represented the intended constructs. Reliability testing was conducted using Cronbach's Alpha with a reliability criterion of $\alpha \geq 0.70$. After the validity and reliability requirements were fulfilled, normality testing was performed using the Shapiro-Wilk test because the sample size was fewer than fifty participants in each group. Homogeneity testing was conducted using Levene's Test to examine the equality of variance between the experimental and control groups. Inferential statistical analysis was subsequently conducted using paired sample t-tests and independent sample t-tests. The paired sample t-test was used to analyze differences between pretest and posttest scores within each group. Meanwhile, the independent sample t-test was conducted to compare posttest results between the experimental and control groups. Statistical analysis was performed using SPSS software with a significance level of 0.05.

Procedure

The research procedure was conducted systematically in several stages to ensure the effectiveness of the learning intervention and data collection process. The first stage involved preliminary observations and interviews with science teachers to identify students' learning conditions, self-awareness levels, and environmental responsibility behavior. Based on the preliminary findings, the researchers developed Project-Based Learning activities related to environmental preservation and sustainability issues. The research instruments and learning materials were then prepared and validated by educational experts before implementation. During the pre-intervention stage, both the experimental and control groups completed pretests to measure students' initial levels of self-awareness and environmental responsibility. The experimental group subsequently participated in Project-Based Learning activities involving contextual environmental projects, collaborative problem-solving, and reflective discussions. Students were actively involved in identifying environmental problems, conducting investigations, designing environmental campaigns, and presenting project outcomes related to environmental preservation. Meanwhile, the control group received conventional science instruction consisting of lectures, question-and-answer activities, and textbook-oriented learning. Throughout the learning activities, classroom observations were conducted to monitor students' participation and engagement during the instructional process. After the intervention was completed, both groups completed posttests to

measure students' improvement after participating in the learning activities. Finally, all collected data were analyzed statistically to determine the effectiveness of Project-Based Learning in enhancing students' self-awareness and environmental responsibility within science education contexts.

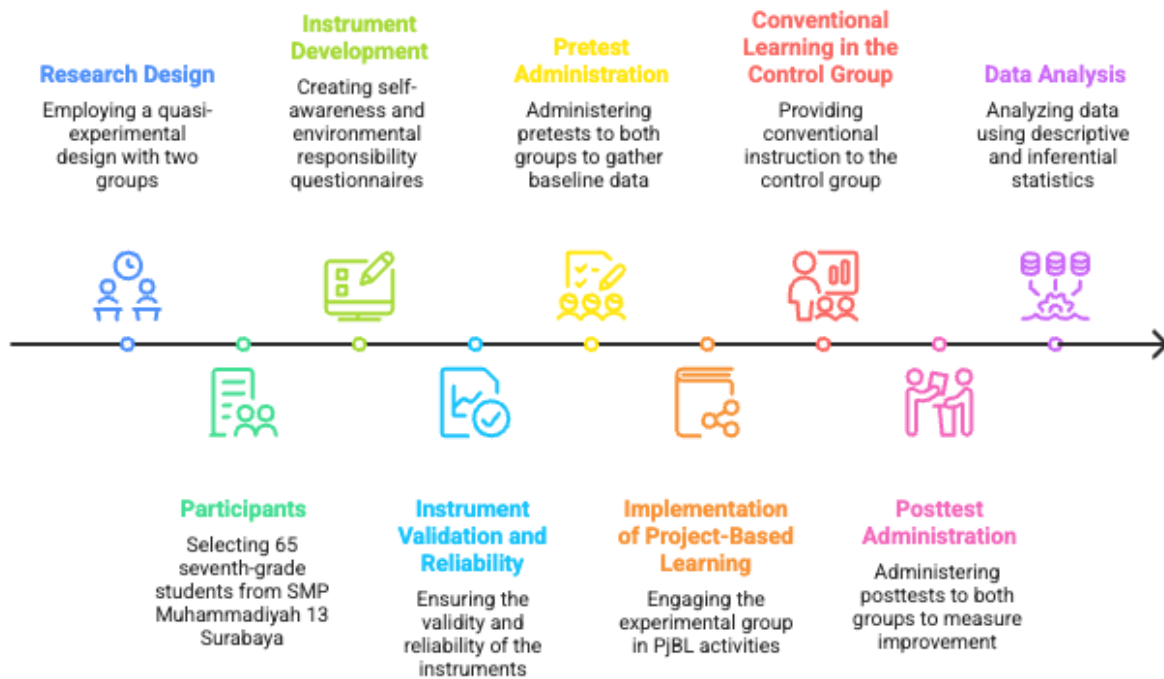


Figure 1. Research Method Flow

RESULTS AND DISCUSSION

Results

Study This was held at Muhammadiyah 13 Middle School, Surabaya, which is one of the medium-sized schools in the private sector under the shade of Muhammadiyah Association. School has its own characteristics, heterogeneous students, good from the aspect of ability, academic background, and social background, as well as the level of awareness of the environment around. Condition the nearby environment with settlement congestion, relevant population. For research that focuses on improving awareness of self-care and the environment. The subject study consists of 65 participants, with 31 students in the control group and 34 students in the experimental group. Each class gets different treatment. However, it refers to the same competence on the same basis in eye science lessons. Before treatment was given, both groups had previously followed a pre-test to assess their knowledge level, beginning with awareness of self and the environment of students. After treatment was given during a number of meetings, a post-test was conducted to measure changes and improvements in scores on both variables. Before being used for collecting research data, this instrument was further validated and tested for reliability to ensure that every statement is worthy of use and has a high level of consistency. After the instrument is declared valid and reliable, the questionnaire is given to respondents at the stage of *pre-test* and *post-test*.

Instrument Validity Test

Testing validity is conducted by researchers as a feasibility test or relevance content test analysis by a panel through *expert judgment*. *Expert judgement* was done by 5 people to assess the items. This was done to know the items that have been arranged according to their own relevance, with the help of a see indicator for every variable. Validity content of the research. This uses Aiken's

V index, which is one of the methods used in a wide range to measure validity content. This technique was developed to measure items with see 3 aspects: clarity, relevance, and appropriateness. Furthermore, the scale selected assessment consists of ' good once ' with score 4, ' good ' with score 3, ' sufficient ' with score 2, and ' less ' with score 1. See an item is valid when it has 5 panelists with 4 raters , namely 0.87 with a level 5% error. Validity Test Results Self- awareness.

Table 7. Validity Test of Self Awareness/ Self-Control

Aspect Evaluation	CVI	CVR	CVR Standard	Significant
Clarity	0,66 to 0,90	0,83	0,87	0,050
Relevance	0,72 to 0,90	0,83	0,87	0,050
Compliance	0,72 to 0,90	0,84	0,87	0,050

Source: Excel Program 19

Based on summary results analysis with CVI and CVR from aspect clarity, the CVR value obtained was 0.83, and the CVI value moved from 0.66 to 0.90. This shows that all items are valid in aspect clarity. However, there is 1 item that must be revised, namely item no. 9. Then in the aspect relevance, obtained CVR value 0.83 and CVI value moving from 0.72 to 0.90. Which means that, on average, all items have aspect relevance. In the aspect of suitability, the mark obtained CVR value 0.84 and CVI value moving from 0.72 to 0.90. Which means all items are ready in their own aspect suitability.

Table 8. The Content Validity Test of Environmental Awareness

Aspect Evaluation	CVI	CVR	CVR Standard	Significant
Clarity	0,66 to 0,90	0,84	0,87	0,050
Relevance	0,72 to 0,90	0,85	0,87	0,050
Compliance	0,72 to 0,90	0,86	0,87	0,050

Source: Excel Program 19

Based on summary results analysis on validity content on the scale awareness environment with CVI and CVR, from the aspect of clarity, the CVR value obtained was 0.84, and the CVI value moved from 0.66 to 0.90. Which means the item has validity in aspects of clarity. However, there is 1 item that must be revised, namely item no. 18. Then, in the aspect relevance, the obtained CVR value was 0.85, and the CVI value moved from 0.72 to 0.90. Which means that the average item has aspect relevance . Continue to the aspect suitability obtained, CVR value 0.86, and CVI value moving from 0.72 to 0.90. Which means that the average item has aspect relevance, and not. There is an item revision.

Reliability Test Instrument

After validity is fulfilled , the next step is conduct reliability testing aimed at assessing the known level of internal consistency between items using Cronbach's Alpha.

Table 9. Reliability Test Result

Cronbach's Alpha	N of Items
0,900	44

Source: SPSS 21

Based on the results data processing, the obtained Cronbach's Alpha value is 0.90, which means the scale has a very good level of reliability. Cronbach's Alpha value ≥ 0.70 indicates that the instrument has adequate and proper internal consistency used in further data collection (Heale & Twycross, 2015). Thus, the results analysis reliability supports that the scale Awareness Self - Control, and Environmental Awareness that is *developed* can be reliable for measuring the construct in accordance with the objective of the study.

Statistics Descriptive

Descriptive statistics analysis was done to get a general description about the average score (mean), the highest and lowest values, and the standard deviation of the two main variables, namely awareness self and awareness environment, both in the class control and the class experiment. Calculation done for the results of the *pre-test* and *post-test* of each class. As for the summary results statistics, the descriptive statistics are presented in the table that follows.

Table 10. Statistics Table Descriptive

Variables	Class	N	Mean	SD	Minimum Value	Maximum Value
Self Awareness (<i>Pre-test</i>)	Control	31	2.85	0.42	2.00	3.67
Self Awareness (<i>Post-test</i>)	Control	31	3.02	0.38	2.25	3.83
Awareness Environment (<i>Pre-test</i>)	Control	31	2.79	0.40	2.00	3.50
Awareness Environment (<i>Post-test</i>)	Control	31	2.95	0.35	2.20	3.75
Self Awareness (<i>Pre-test</i>)	Experiment	34	2.84	0.41	2.00	3.60
Self Awareness (<i>Post-test</i>)	Experiment	34	3.35	0.32	2.70	3.90
Awareness Environment (<i>Pre-test</i>)	Experiment	34	2.77	0.43	2.00	3.67
Awareness Environment (<i>Post-test</i>)	Experiment	34	3.40	0.31	2.80	3.90

Source: SPSS 21

Based on Table 10, it can be known that in a way, a general happen improvement in average value (mean) occurs in both the class control and the class experiment. In class control, the average score of awareness self increased from 2.85 at the time of the *pre-test* to 3.02 in the *post-test*, with a difference of 0.17 points. Likewise, in the variable awareness environment, the average increased from 2.79 to 2.95 with an improvement of 0.16 points. Standard value relatively small deviation (between 0.35-0.42) indicates that sufficient data distribution is homogeneous, or not too varied between respondents. In the class experiment, there was further improvement in terms of tall awareness, namely, with an average awareness score self-increase from 2.84 to 3.35, with an improvement of 0.51 points, while the average awareness environment increased from 2.77 to 3.40, with an improvement of 0.63 points. Standard value relative deviation is small on the post-test (around 0.31-0.32), indicating that after learning based project (PjBL) is implemented, the variation in scores between participants is smaller, which means most students show sufficient improvement and awareness evenly.

Normality Test and Homogeneity

Normality test was done using the method Shapiro-Wilk, because the number of respondents in each group was not large enough, 50. The results show that all data have a mark significance > 0.05 , so that they are normally distributed and meet the conditions for using parametric tests (*t-test*), as shown in the table following:

Table 11. Normality Test

E			Shapiro-Wilk		
Statistic	Df	Sig.	Statistic	df	Sig.
.115	31	.200*	.972	31	.574
.106	31	.200*	.957	31	.241
.130	34	.153	.978	34	.704
.085	34	.200*	.965	34	.343

Source: SPSS 21

Homogeneity test results use *Levene's Test*, obtained Sig. value = 0.130 > 0.05 , which means the variance of the second group is homogeneous. This shows that the second group has equality variance and can be compared in a legitimate way using the *t-test*.

Table 12. Homogeneity Test

Levene Statistic	df1	df2	Sig.
1.919	3	126	.130

Source: SPSS 21

Hypothesis Testing

This test aims to know the influence of the application of learning models, Project-Based Learning (PBL), on the improvement of pretest–posttest scores in a group experiment.

Table 13 Paired t-Test (Within Groups Experiment)

Pasangan	Mean Difference	T	Sig. (2-tailed)	Interpretasi
Pretest – Posttest	-3.26471	6.935	0.000	Signifikan

Source: SPSS 21

Sig value. = 0.000 < 0.05 indicates improvement is significant after treatment. This means that the application of PjBL is effective in increasing awareness of self and the care environment of students.

Table 14. Sample t- Test (Between Groups)

Sig. (Levene)	Sig. (t-test)	Mean Difference	Interpretasi
0.008	0.001	-6.373	Perbedaan signifikan

Source: SPSS 21

Sig value. (2-tailed) = 0.001 < 0.05 shows a significant difference between the second posttest results group. The average posttest of the group experiment was 6,373 points, indicating that learning based project is more effective than learning conventional learning.

Discussion

The findings of this study indicate that the instruments used to measure self-awareness and environmental responsibility possessed strong validity and reliability, demonstrating their suitability for educational research contexts. The content validation process conducted through expert judgment confirmed that the questionnaire items adequately represented the intended constructs of reflective awareness and environmental responsibility. The Aiken's V scores ranging from 0.66 to 0.90 suggest that the questionnaire items were relevant, clear, and appropriate for measuring students' attitudes and behaviors. Although several items required revision during the validation process, the overall quality of the instrument remained highly acceptable for subsequent data collection. Furthermore, the reliability coefficient obtained through Cronbach's Alpha analysis reached 0.900, indicating excellent internal consistency among the questionnaire items. These findings are consistent with previous educational studies emphasizing that reliable and valid instruments are essential for obtaining accurate measurements of affective and behavioral educational outcomes (X. Chen et al., 2024; Ng et al., 2024). The strong psychometric properties of the instruments strengthen the credibility of the findings regarding students' self-awareness and environmental responsibility. Similar studies on project-based and character-oriented learning have also highlighted the importance of rigorous validation procedures to ensure accurate representation of students' reflective and environmental competencies (Lai & Hu, 2025). The validity and reliability findings therefore support the conclusion that the developed questionnaires effectively measured the intended dimensions of reflective awareness and environmental care. Consequently, the methodological rigor applied in this study contributes positively to the reliability and trustworthiness of the research findings within science education contexts.

The statistical analysis results demonstrated that Project-Based Learning significantly improved students' self-awareness and environmental responsibility compared to conventional instructional approaches. The paired sample t-test revealed a statistically significant difference between pretest and posttest scores in the experimental group, indicating that the implementation of Project-Based Learning produced meaningful educational improvement. In addition, the independent sample t-test confirmed significant differences between the experimental and control groups after the intervention, with the experimental group achieving substantially higher posttest scores. These findings indicate that students who participated in Project-Based Learning activities experienced greater development in reflective awareness and environmental responsibility than students who received conventional lecture-based instruction (Hou et al., 2023; Paleenud et al., 2024). Similar findings have been reported in previous studies demonstrating that project-oriented learning environments improve students' engagement, reflective thinking, and social responsibility through active participation in authentic learning experiences (Chang et al., 2022b; Hou et al., 2023; Shi & Li, 2024). The improvement observed in this study may be attributed to the contextual and experiential nature of Project-Based Learning, which allows students to connect scientific concepts with real environmental issues. Through collaborative projects, students actively explored environmental problems, discussed possible solutions, and reflected on their individual and collective responsibilities toward environmental preservation. In contrast, conventional instructional methods often position students as passive recipients of information, limiting opportunities for active inquiry and reflective engagement. Previous research has similarly indicated that teacher-centered learning approaches are less effective in promoting social-emotional development and environmental awareness among adolescents. Therefore, the findings of this study further strengthen the growing body of evidence supporting Project-Based Learning as an effective instructional strategy for integrating science learning with character and sustainability education.

The improvement in students' self-awareness observed during the implementation of Project-Based Learning can also be explained through constructivist learning theory and reflective learning perspectives. Constructivist theory emphasizes that knowledge and awareness are developed through active interaction with authentic experiences and meaningful social engagement. During the project activities, students were required to recognize their strengths, evaluate their learning processes, manage emotions, and collaborate effectively with peers. These learning experiences encouraged students to become more reflective regarding their actions, responsibilities, and contributions during project completion. Reflective discussions conducted throughout the project implementation process also supported students in developing emotional regulation and interpersonal awareness. Similar studies have shown that project-based and experiential learning environments positively influence students' self-regulation, confidence, and reflective thinking because students become directly involved in decision-making and problem-solving processes (Alvi & Gillies, 2021; Green & Du Plessis, 2023; Gu et al., 2025; Shekh-Abed, 2025). The findings of this study are also aligned with self-determination theory, which explains that autonomy, competence, and active participation enhance intrinsic motivation and personal awareness. Through Project-Based Learning, students experienced greater autonomy in planning and implementing project activities, which strengthened their sense of responsibility and self-confidence. Collaborative learning activities additionally promoted social interaction and empathy among students, enabling them to recognize their roles within group learning processes more effectively. Therefore, the implementation of Project-Based Learning not only enhanced cognitive understanding but also supported the development of reflective awareness and emotional maturity among junior high school students.

The findings regarding environmental responsibility further demonstrate the importance of contextual environmental projects in fostering environmentally responsible behavior among

adolescents. Students who participated in Project-Based Learning activities showed increased awareness regarding environmental cleanliness, waste management, and environmental preservation practices. The implementation of projects such as recycling activities, environmental campaigns, and waste management programs encouraged students to understand the direct consequences of environmental problems within their surroundings. These experiences enabled students to establish stronger emotional connections with environmental sustainability issues because learning was directly linked to real-world environmental conditions. Similar studies have reported that environmental project-based learning positively influences students' environmental ethics, pro-environmental behavior, and ecological awareness (Kosherbayeva et al., 2026; Mahidol University International College, Thailand et al., 2020; Qin & Qin, 2024; Xi & Wang, 2022). Environmental education scholars have also argued that authentic environmental experiences are more effective in promoting sustainable behavior than purely theoretical classroom instruction. Through collaborative environmental projects, students became more aware of their individual and collective responsibilities toward maintaining environmental quality within the school environment. The collaborative nature of Project-Based Learning additionally strengthened social responsibility because students worked together to achieve common environmental goals. Previous studies have similarly found that students who engage directly in environmental action projects are more likely to demonstrate long-term environmental concern and sustainable behavior. In this study, the improvement in environmental responsibility was reflected not only in statistical outcomes but also in students' active participation during environmental preservation activities throughout the learning process. Therefore, Project-Based Learning can be considered an effective educational strategy for integrating environmental sustainability values into science learning activities at the secondary school level.

Despite the positive outcomes identified in this study, several limitations should be considered when interpreting the findings and their broader educational implications. The research was conducted within a single school context involving a relatively limited number of participants, which may restrict the generalizability of the findings to other educational environments. Differences in school culture, environmental conditions, and students' social backgrounds may influence the effectiveness of Project-Based Learning implementation in different contexts. In addition, the duration of the intervention was relatively short, limiting the ability to evaluate the long-term sustainability of students' reflective awareness and environmental responsibility development. The use of self-report questionnaires may also introduce response bias because students may provide socially desirable answers during the data collection process. Nevertheless, the study contributes significantly to science education literature by demonstrating that Project-Based Learning can effectively integrate character education and environmental sustainability within classroom learning activities. The findings also suggest that science learning should move beyond cognitive achievement and incorporate reflective awareness, emotional development, and environmental responsibility as essential educational outcomes. Future studies are recommended to involve larger and more diverse participant groups, longer intervention periods, and mixed-method approaches to obtain more comprehensive insights into the effectiveness of Project-Based Learning. Additional research may also examine the influence of Project-Based Learning on other educational variables such as scientific literacy, collaboration skills, creativity, and environmental ethics. Therefore, continued investigation into Project-Based Learning and sustainability-oriented science education remains important for developing more holistic, contextual, and meaningful educational practices in modern schools.

Implications

The findings of this study provide important implications for the development of science education, particularly in integrating character education and environmental sustainability within

classroom learning activities. The successful implementation of Project-Based Learning demonstrates that science learning should not solely emphasize cognitive achievement but also promote reflective awareness and environmentally responsible behavior among students. The study indicates that contextual and project-oriented learning experiences can effectively encourage students to become active participants in solving real environmental problems within their surroundings. Through collaborative environmental projects, students are able to develop stronger emotional awareness, responsibility, and social engagement during the learning process. These findings imply that teachers should adopt more student-centered instructional approaches that provide opportunities for inquiry, reflection, collaboration, and authentic problem-solving experiences. The integration of environmental issues into science learning also supports the development of sustainable character and ecological consciousness among adolescents. Furthermore, the results suggest that Project-Based Learning can serve as an effective pedagogical strategy for strengthening social-emotional competencies and environmental ethics simultaneously. Educational institutions may therefore consider integrating contextual environmental projects into science curricula to foster students' active involvement in environmental preservation efforts. The study additionally highlights the importance of designing learning environments that connect scientific concepts with students' real-life experiences and community issues. From a practical perspective, the implementation of Project-Based Learning can help schools create more meaningful and engaging learning experiences that support holistic student development. From a theoretical perspective, the findings strengthen constructivist and experiential learning theories by demonstrating that reflective awareness and environmental responsibility can be developed through authentic learning experiences and active participation. Therefore, this study contributes to the advancement of sustainability-oriented science education by providing empirical evidence that Project-Based Learning can effectively support the formation of reflective, socially responsible, and environmentally conscious students in secondary education contexts.

Limitations and Suggestions for Future Research

Although this study demonstrated that Project-Based Learning effectively enhanced students' self-awareness and environmental responsibility, several limitations should be acknowledged when interpreting the findings. First, the study was conducted in a single private junior high school with a relatively limited number of participants, which may reduce the generalizability of the results to broader educational contexts. Second, the duration of the learning intervention was relatively short, making it difficult to evaluate the long-term sustainability of students' reflective awareness and environmentally responsible behavior after the completion of the project activities. Third, the study relied primarily on self-report questionnaires, which may introduce response bias because students could provide socially desirable answers during the data collection process. Fourth, the research focused only on two affective variables, namely self-awareness and environmental responsibility, without examining other potentially relevant educational outcomes such as scientific literacy, collaboration skills, creativity, and problem-solving abilities. In addition, differences in students' social backgrounds, classroom environments, and prior environmental experiences were not analyzed comprehensively in this study. The implementation of Project-Based Learning was also limited to science learning contexts related to environmental issues, which may not fully represent the effectiveness of the model across different science topics or educational disciplines. Furthermore, the study employed a quantitative approach only, thereby limiting deeper exploration of students' reflective experiences and behavioral changes during the project activities. Future studies are therefore recommended to involve larger and more diverse participant groups from different educational institutions and geographical settings. Longitudinal studies are also necessary to examine the long-term influence of Project-Based Learning on students'

character development and environmental responsibility. In addition, future research should integrate mixed-method approaches by combining quantitative and qualitative data to obtain more comprehensive insights into students' learning experiences and reflective processes. Further investigations may also explore the integration of Project-Based Learning with digital technology, community-based environmental programs, or interdisciplinary science learning to strengthen sustainability-oriented education in modern schools.

CONCLUSION

This study concludes that the implementation of Project-Based Learning (PjBL) effectively enhanced students' self-awareness and environmental responsibility in junior high school science education at SMP Muhammadiyah 13 Surabaya. The findings demonstrated that students who participated in project-based science learning activities showed significantly greater improvement compared to students who received conventional instructional approaches. The statistical analysis confirmed significant differences between pretest and posttest scores in the experimental group, indicating that Project-Based Learning positively influenced students' reflective awareness and environmentally responsible behavior. The implementation of contextual environmental projects enabled students to become actively involved in identifying environmental problems, designing practical solutions, and reflecting on their personal responsibilities toward environmental sustainability. Through collaborative and inquiry-based activities, students developed stronger emotional awareness, communication skills, social responsibility, and environmental consciousness during the learning process. The findings also demonstrated that authentic and experiential learning experiences provide meaningful opportunities for students to connect scientific concepts with real-life environmental challenges. In addition, the validity and reliability analyses confirmed that the developed research instruments were appropriate and consistent for measuring students' self-awareness and environmental responsibility. The study further supports constructivist and experiential learning theories, which emphasize that meaningful learning occurs through active participation and direct interaction with authentic situations. Project-Based Learning was also found to create more engaging, student-centered, and reflective learning environments compared to conventional teacher-centered instruction. From a practical perspective, the findings suggest that science teachers should integrate contextual environmental projects into classroom learning activities to support character development and sustainability education. From a theoretical perspective, this study contributes empirical evidence regarding the effectiveness of Project-Based Learning in promoting reflective awareness and environmental responsibility simultaneously within science education contexts. Therefore, Project-Based Learning can be considered an effective pedagogical strategy for fostering environmentally conscious, socially responsible, and reflective students in modern secondary education.

AUTHOR CONTRIBUTIONS STATEMENT

Devie Silfiyani Sahrída was responsible for the research conceptualization, instrument development, data collection, implementation of Project-Based Learning activities, statistical analysis, and manuscript drafting. Beti Istanti Suwandani contributed to the research supervision, methodological validation, data interpretation, and provided critical revisions to improve the quality of the manuscript. Agus Tinus contributed to the research design refinement, validation of the research instruments, theoretical framework development, and final manuscript review. All authors participated in the discussion of the findings, approved the final version of the manuscript, and agreed to be accountable for all aspects of the research.

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