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Project-based learning on environmental change to enhance numeracy skills and environmental awareness to support SDGs 13

Tari Anjani [1], Wiwit Artika [1, 3] *, Rahmah Johar [2], Andi Ulfa Tenri Pada [1], M. Ali Sarong [1]

[1] Master Program of Biology Education, Faculty of Teacher and Education, Universitas Syiah Kuala, Banda Aceh, Aceh, Indonesia
[2] Master Program of Mathematics Education, Faculty of Teacher and Education, Universitas Syiah Kuala, Banda Aceh, Aceh, Indonesia
[3] Research Centre for Social and Cultural Studies, Universitas Syiah Kuala, Banda Aceh, Aceh, Indonesia

** Corresponding Author Email: wartika@usk.ac.id*

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Abstract

Numeracy skills and an environmental care attitude are essential competencies for environmental sustainability, yet both are currently low among students. This study aimed to: (1) analyze the enhancement of students' numeracy skills, (2) evaluate the improvement of their environmental care attitude through a project-based learning model, and (3) determine differences in these competencies based on gender. A quantitative approach with a pretest-posttest control group experimental design was employed. The sample comprised 32 tenth-grade students selected via purposive sampling. The t-test analysis showed a significant difference between the experimental and control groups (Sig. 2–tailed<0.05), confirming the effectiveness of project-based learning (PjBL) in improving numeracy and environmental care attitude. Furthermore, significant gender differences were observed, males scored higher in numeracy, while females scored higher in environmental care attitude. These findings affirm the importance of integrating numeracy and environmental issues into learning as a tangible strategy to support SDG 13. The project-based learning model is effective in improving environmental data analysis skills and climate mitigation awareness. This model is recommended for fostering students who are critical thinkers and possess pro-environmental behavior.

Abstrak. *Kemampuan numerasi dan sikap peduli lingkungan merupakan dua kompetensi esensial dalam mendukung keberlanjutan lingkungan, namun keduanya masih rendah di kalangan siswa. Penelitian ini bertujuan untuk: (1) menganalisis peningkatan kemampuan numerasi siswa, (2) mengevaluasi peningkatan sikap peduli lingkungan melalui model pembelajaran berbasis proyek, dan (3) mengetahui perbedaan kompetensi tersebut berdasarkan gender. Penelitian ini menggunakan pendekatan kuantitatif dengan desain eksperimen pretest-posttest control group. Sampel penelitian terdiri atas 32 siswa kelas X SMA Negeri Modal Bangsa yang dipilih melalui purposive sampling. Instrumen penelitian berupa tes numerasi dan angket. Hasil analisis uji-t menunjukkan adanya perbedaan signifikan antara kelompok eksperimen dan kontrol (Sig. 2-tailed < 0,05), yang menegaskan efektivitas pembelajaran berbasis proyek (PjBL) dalam meningkatkan kemampuan numerasi dan sikap peduli lingkungan. Selain itu, ditemukan perbedaan signifikan berdasarkan gender, yaitu siswa laki-laki memperoleh skor rata-rata lebih tinggi pada kemampuan numerasi, sedangkan siswa perempuan memperoleh skor rata-rata lebih tinggi pada sikap peduli lingkungan. Temuan ini menegaskan pentingnya integrasi numerasi dan isu lingkungan dalam pembelajaran sebagai strategi nyata mendukung SDG 13. Pembelajaran berbasis proyek efektif meningkatkan kemampuan analisis data lingkungan dan kesadaran mitigasi iklim. Model ini direkomendasikan untuk membentuk peserta didik yang berpikir kritis dan berperilaku pro-lingkungan.*

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A. Introduction

The Sustainable Development Goals (SDGs) are a global agenda formulated by the United Nations (UN) in 2015 as a collective effort to address multidimensional challenges in the economic, social, and environmental domains (Hák et al., 2016). The SDGs comprise 17 interrelated goals, including poverty eradication, women's empowerment, quality education, biodiversity conservation, and climate action (Kroll et al., 2019; Sachs et al., 2019). Through a holistic and inclusive approach, the SDGs are designed to ensure sustainable development that not only meets the needs of the present generation but also guarantees sustainability for future generations (Jaca-García et al., 2020). In Indonesia, the implementation of the SDGs is regulated by Presidential Regulation Number 59 of 2017, which serves as a guideline for translating global goals into national policies (Bappenas, 2018).

SDG 4 (Quality Education) emphasizes the importance of inclusive and equitable education, as well as lifelong learning opportunities (UNESCO, 2015). In this context, literacy and numeracy skills serve as key indicators at the primary and secondary education levels (OECD, 2023). Numeracy encompasses competencies in arithmetic, algebra, geometry, critical thinking, problem-solving, and the ability to make decisions based on mathematical information.

However, Indonesian students' numeracy skills remain relatively low. The 2022 Minimum Competency Assessment (AKM) revealed that only 40.63% of junior high school students (SMP/MTs) achieved the minimum numeracy competency level (Pusmendik-Kemendikbud, 2023), while the 2022 PISA results placed Indonesia at 70th out of 81 participating countries (OECD, 2023). This low achievement has been associated with teacher-centered learning and the limited integration of real-world contexts into the learning process (Rohmah et al., 2022; Iswara et al., 2022).

Furthermore, the issue of environmental change related to SDG 13 (Climate Action) has also become a pressing concern. SDG 13 not only demands awareness of climate change but also requires the achievement of concrete indicators, such as increasing knowledge and adaptive capacity to the impacts of climate change, and integrating climate issues into policy, education, and daily practices (United Nations, 2015).

Human activities, including industry, transport, and agriculture, contribute to pollution and greenhouse gas emissions, thereby accelerating climate change and damaging ecosystems (Ioannou et al., 2023). Within the context of education, contributing to the achievement of SDG 13 can be realized through the integration of climate change issues into the curriculum, the enhancement of students' climate literacy, and the strengthening of an environmental care attitude (Galvin, 2025). Thus, education plays a strategic role in equipping the younger generation to actively participate in climate change mitigation and adaptation.

To address the challenges of low numeracy skills and a lack of environmental awareness, various instructional strategies have been implemented globally. One relevant approach is interactive, collaborative, and student-centered learning, such as PjBL (Getenet & Beswick, 2021). The PjBL encourages students' active engagement in solving real-world problems, developing critical and creative thinking skills, and integrating various disciplines (Almulla, 2020). Through integration with the Education for Sustainable Development (ESD) approach, PjBL not only strengthens academic abilities but also supports SDG 13 indicators, specifically enhancing climate literacy and student participation in the context of sustainability (Lozano et al., 2022).

Environmental change materials can be used as a context in PjBL to enable students to analyze data, understand human–environment interactions, and build ecological awareness. In this way, students not only learn scientific content but also strengthen their numeracy skills within an authentic and meaningful context. Previous studies have shown that PjBL can enhance knowledge, attitudes, and skills (Duke et al., 2021; Wulandari, 2016; Tyaningsih et al., 2023), as well as foster environmental awareness and improve students' numeracy (Rizki & Nuranti, 2022). However, research specifically integrating environmental change material with numeracy enhancement within the PjBL model, and explicitly linked to SDG 13 indicators, remains highly limited. This gap necessitates further investigation.

In addition, gender differences in numeracy skills and environmental care attitude are not only a national issue but also an international concern. Studies by PISA (OECD, 2023) indicate that, globally, male students tend to achieve higher scores in numeracy compared to female students. Meanwhile, Xiao and McCright (2015) demonstrates that females consistently exhibit a higher pro-environmental attitude than males. This distinction is relevant not only to SDG 13 (Climate Action) but also to SDG 5 (Gender Equality), as these differences underscore the importance of gender-responsive educational strategies to ensure equal participation between males and females in both numeracy skills and environmental care attitude.

Based on the preceding discussion, this research aims to test the effectiveness of the project-based learning model in enhancing students' numeracy skills and environmental awareness through the integration of environmental change material. Simultaneously, it seeks to make a concrete contribution to the achievement of SDG 13 (Climate Action), specifically concerning the indicators for increasing education, awareness, and adaptive capacity to climate change,

and to examine gender differences in students' numeracy skills and environmental care attitude.

This research supports and extends previous findings regarding the effectiveness of PjBL in enhancing student engagement, conceptual understanding, and 21st-century skills. However, differing from prior studies that generally focused on strengthening cognitive aspects or attitudes in isolation, this investigation methodologically integrated the context of environmental change into Biology learning activities as an effort to support SDG 13 (Climate Action). Simultaneously, it aimed to develop students' numeracy skills through the analysis of data based on contextual environmental issues.

Furthermore, this study explicitly examined gender differences in the achievement of numeracy skills and environmental care attitude, a dimension rarely discussed concurrently in previous research. With this approach, the study provides a substantive contribution by enriching the PjBL model based on environmental content, focusing not only on conceptual understanding but also on reinforcing numeracy literacy as a foundation for decision-making regarding climate change issues.

B. Material and method

This research employed a quantitative approach with an experimental research design, specifically utilizing a quasi-experimental method. The population for this study comprised all tenth-grade students at SMA Negeri Modal Bangsa. The research sample consisted of two classes, namely Class X-4 serving as the experimental class and Class X-5 as the control class, with each class consisting of 32 students. Sampling was conducted using the purposive sampling technique.

The data collection procedure was carried out using two instruments. Numeracy skills were measured through pretest and posttest scores administered before and after the implementation of the project-based learning model. Meanwhile, data on environmental awareness were obtained through a questionnaire administered after the implementation. of the project-based learning model.

The numeracy test instrument was developed based on the indicators proposed by Han et al. (2017), which include the use of symbols and numbers, analysis of information from graphs, tables, and diagrams, as well as the interpretation of numerical results for decision-making. The environmental awareness questionnaire was adapted from the design of Ayuanita (2017) in accordance with the indicators of the General Ecological Behavior Scale (GEBS) by Kaiser (2020), covering energy conservation, waste avoidance, consumerism, recycling and vicarious behaviors, as well as social behaviors toward conservation.

The quality of the instruments was assessed through validity and reliability testing. The validity of the test and questionnaire instruments was examined using Aiken's V formula to evaluate the alignment of each item with the measured indicators, based on expert judgment (Aiken, 1985) (see Formula 1).

$$V = \frac{\sum S}{n\,(c-1)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Formula 1}$$

Description:
S = r-lo
V = instrument validity
N = number of raters
c = highest validity rating score

Furthermore, the reliability of the test instrument was analyzed using the Spearman–Brown formula to determine the internal consistency among the test items, while the reliability of the questionnaire was analyzed using the item-total correlation coefficient (Arikunto, 2013) (see Formula 2).

$$r_{11} = \frac{2xr_{1/21/2}}{1 + r_{1/21/2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Formula 2}$$

The validity test results of the numeracy instrument showed that all items obtained Aiken's V values above 0.667, indicating validity based on Aiken's interpretation criteria. The reliability test of the instrument yielded a coefficient of 0.80, which falls into the high category according to the Spearman–Brown interpretation. The validity test results of the questionnaire indicated that the correlation values of all items were above 0.20, meaning that all items were considered valid. The reliability test of the questionnaire produced a coefficient of 0.883, which belongs to the very high category. Therefore, both the test instrument and the questionnaire were deemed appropriate for use in this study.

The data analysis technique for numeracy skills was conducted by calculating the N-Gain values based on the pretest and posttest scores, followed by tests of normality and homogeneity. Subsequently, an independent sample t-test was performed on the N-Gain values to examine the differences in improvement between the experimental and control classes. For the analysis of environmental awareness, the questionnaire results were tested for normality using the Kolmogorov–Smirnov method, and the homogeneity of variances was assessed using Levene's test. An independent sample t-test was then conducted. All analyses were carried out using SPSS version 26.

C. Results and discussion

The data discussed in this study include the results of normality and homogeneity tests, N-Gain values, and independent sample t-tests. The normality test was conducted prior to the homogeneity test and other prerequisite tests. To examine data normality, the One-Sample Kolmogorov–Smirnov Test was applied. The

normality test was performed on the environmental awareness questionnaire scores and the mean N-Gain scores from the pretest and posttest of the control and experimental classes. The decision-making criteria in the normality test were as follows: if the significance value was greater than 0.05, the data were considered normally distributed; conversely, if the significance value was less than 0.05, the data were considered not normally distributed.

The homogeneity test was conducted after the data met the normality requirements. Once normality was confirmed, homogeneity was tested using Levene's Test of Equality of Error Variances. The data analyzed were derived from the environmental awareness questionnaire scores and the mean N-Gain scores from the pretest and posttest of the control and experimental classes. The purpose of the homogeneity test was to determine the uniformity of the data. If the significance value was greater than 0.05, the data were considered homogeneous; however, if the significance value was less than 0.05, the data were considered not homogeneous.

Table 1 Results of normality and homogeneity tests of N-Gain scores for numeracy skills

Variable	Normality	Homogeneity
Experimental	0.263 (Normal)	0.234
Control	0.378 (Normal)	(Homogeneous)

Table 2 Results of normality and homogeneity tests of scores questionnaire scores on environmental awareness attitudes

Variable	Normality	Homogeneity
Experimental	0.378 (Normal)	0.304
Control	0.554 (Normal)	(Homogeneous)

Table 3 Results of data analysis on differences in improvements in numeracy skills

Class	Mean	SD	t-test	Sig
Experimental	0.60	0.22	5.670	0.000*
Control	0.42	0.26		

Table 4 Results of data analysis on differences in attitudes toward environmental awareness

Class	Mean	SD	t-test	Sig
Experimental	80.31	0.15	3.178	0.002*
Control	71.06	0.22		

Based on the results of the normality and homogeneity tests of the mean N-Gain presented in Table 1, the significance value of the normality test for the experimental class was 0.263 and for the control class was 0.378. Both values were greater than 0.05, indicating that the N-Gain data of numeracy skills in both classes were normally distributed. Furthermore, the results of the homogeneity test showed a significance value of 0.234 (> 0.05). This means that the N-Gain data from the experimental and control classes had homogeneous variances.

Furthermore, based on the results of the normality and homogeneity tests of the questionnaire scores presented in Table 2, the significance value of the normality test for the experimental class was 0.378 and for the control class was 0.554. Both values were greater than 0.05, indicating that the environmental awareness attitude questionnaire scores in both classes were normally distributed. The results of the homogeneity test showed a significance value of 0.304 (> 0.05). This means that the questionnaire scores on environmental awareness attitudes between the experimental and control classes were homogeneous.

After the data met the assumptions of normality and homogeneity, hypothesis testing was carried out using an independent samples t-test. The decision-making criterion was that if the Sig. (2-tailed) value was less than 0.05, then H0 was rejected and the research hypothesis was accepted; whereas if the Sig. (2-tailed) value was greater than 0.05, then H0 was accepted and the research hypothesis was rejected.

The improvement of numeracy skills was analyzed based on the results of the pretest and posttest. As presented in Table 3, the average N-Gain of students' numeracy skills in the experimental class reached 0.60 with a standard deviation of 0.22, while in the control class the average N-Gain was 0.42 with a standard deviation of 0.26. The t-test analysis showed a value of t = 5.670 with Sig. = 0.000 (< 0.05), indicating that H0 was rejected and the research hypothesis was accepted. This finding demonstrates a significant difference in the improvement of numeracy skills between the experimental class and the control class.

This difference indicates that the PjBL model implementation has a positive effect on improving students' numeracy skills. The PjBL trains students to

apply knowledge to real-world contexts through problem-solving and contextual projects. In practice, students are encouraged to think critically, analyze data, and apply mathematical concepts to address environmental issues (Kurniawan et al., 2022).

Through thematic projects, students not only gain an understanding of environmental change concepts but also establish connections between these phenomena and numeracy concepts, such as reading graphs, analyzing tables, and interpreting data analysis results (Akman et al., 2020). This process enhances meaningful learning and retention, as they are able to identify patterns and derive meaning from the data they encounter.

This study is also supported by the findings of Mardhiati (2022), which demonstrate that PjBL is effective in improving numeracy through exploratory activities and data-based problem solving. In addition, Rahmi et al. (2025) found that integrating numeracy into projects encourages students to apply logic and statistical analysis when addressing real-world problems.

During the learning process, students were guided to connect mathematical concepts with environmental issues. The "fundamental question" phase in PjBL serves as a catalyst for exploring and constructing knowledge through the presentation of data and contextual problem-solving (Natty et al., 2019). Stimuli presented in the form of environmental graphs or datasets encourage students to use symbols, numbers, and logic in decision-making (Scott, 2021). Thus, numeracy indicators such as interpreting data, calculating percentage changes, and drawing conclusions from analytical results can be strengthened (Nurcahyono, 2023).

These findings indicate that numeracy-based PjBL learning tools (learning modules, student worksheets, test instruments) can stimulate students to construct understanding of environmental change material through the integration of mathematical concepts. This also demonstrates that such a learning approach is not only relevant for achieving academic competencies but also serves as a strategy that supports contextual, problem-based learning.

Differences in environmental awareness attitudes were analyzed by comparing the experimental class and the control class. As shown in Table 4, the average attitude score in the experimental class was 80.31 with a standard deviation of 0.15, while in the control class the average score was 71.06 with a standard deviation of 0.22. The t-test results showed a value of t = 3.178 with a significance value (Sig.) = 0.002 (< 0.05), indicating that H_0 was rejected and the research hypothesis was accepted. Thus, there was a significant difference in environmental awareness attitudes between the experimental and control classes, with students in the experimental class demonstrating a more positive improvement compared to those in the control class.

This difference indicates that the numeracy-integrated PjBL model can foster students' environmental awareness. Through project activities, students not only learn conceptually while directly engaging and finding solutions to real environmental problems (Wijayanti, 2025). The model further encourages collaboration, discussion, and active student participation in designing and implementing projects that focus on everyday environmental issues (López, 2024).

Environmental awareness is a crucial aspect in supporting the achievement of Sustainable Development Goal (SDG) 13, *Climate Action*, which emphasizes the urgent need to address climate change and its impacts (United Nations, 2015). In the field of education, project-based learning serves as an effective contextual approach to fostering students' environmental awareness, as it encourages their active engagement with real-world issues in their surroundings (UNESCO, 2015).

The concept of project-based learning positions environmental change issues as an essential context for enhancing student engagement. Topics such as global warming, pollution, and environmental degradation serve as entry points to build students' eco-social awareness of human impacts on nature (Molefhi, 2021). In this context, the integration of numeracy enables students to read and interpret data related to environmental issues, such as temperature trends, pollution indices, and environmental degradation statistics (Vásquez et al., 2023).

These results are reinforced by the findings of Luthfina (2024), which indicate that PjBL integrated with numeracy helps foster environmental awareness by encouraging students to analyze environmental data presented in graphs, tables, and diagrams. Espino-Díaz et al. (2025) also emphasized that this model is relevant to sustainable education, as it combines cognitive and affective aspects into a holistic learning experience.

In this study, the project focused on creating infographics on environmental pollution, covering its causes, impacts, and possible mitigation strategies. This project activity encouraged students to critically analyze environmental problems and formulate solutions through tangible outputs such as infographics, digital campaigns, or data-driven presentations. Such activities foster empathy, awareness, and social responsibility toward sustainability issues (Mujiburrahman et al., 2022). Project-based learning also nurtures students' concern and sense of responsibility for environmental challenges, aligning with climate change mitigation efforts outlined in SDG 13 targets (Intergovernmental Panel on Climate Change, 2022). Moreover, students' engagement in contextual and meaningful activities can enhance motivation and deepen their understanding of environmental issues (Barrón, 2022).

Gender is one of the key factors influencing the development of students' cognitive abilities and affective attitudes. In the learning context, gender differences often emerge not only in academic achievement but also in the expression of attitudes toward the surrounding environment. These differences are not solely rooted in biological factors but are also shaped by social constructions, parenting styles, and learning experiences that students are exposed to from an early age (Hentges, 2018).

Table 5 Differences in improvements in numeracy ability based on gender

Gender	Mean	SD	t-test	Sig
Man	73.17	15.61	2.934	0.005
Woman	60.37	17.61		

Table 6 Differences in attitudes toward environmental awareness based on gender

Gender	Mean	SD	t-test	Sig
Man	65.21	12.137	5.031	0.000
Woman	80.38	11.394		

Differences in numeracy ability were analyzed using numeracy test results grouped by gender. Based on Table 5, the average numeracy score of male students was 73.17 with a standard deviation of 15.61, while female students obtained an average score of 60.37 with a standard deviation of 17.61. The results of the t-test showed a value of t = 2.934 with Sig. = 0.005 (< 0.05), indicating that H0 was rejected and the research hypothesis was accepted. This finding demonstrates a significant difference in numeracy ability between male and female students.

These differences indicate that male students tend to perform better in numeracy tasks compared to female students. This result is consistent with the findings of Cook (2018), who reported variations in numeracy achievement across genders in several countries, although the educational context plays an important role in narrowing the gap. The advantage of male students in numeracy may be explained by social factors and learning experiences, where male students are often more frequently exposed to activities involving numbers and logical reasoning. Therefore, it is crucial for teachers to design learning strategies that strengthen female students' numeracy skills in order to prevent significant disparities.

Meanwhile, students' environmental awareness also showed differences based on gender. As presented in Table 6, the average environmental awareness score of female students was 80.38 with a standard deviation of 11.39, which was higher than that of male students, who scored an average of 65.21 with a standard deviation of 12.14. The results of the t-test showed a value of t = 5.031 with Sig. = 0.000 (< 0.05), indicating a significant difference in environmental awareness between male and female students.

This finding suggests that female students tend to consistently demonstrate greater environmental awareness compared to male students. The result is consistent with the study by Nunez and Clores (2017), which explained that females generally show stronger tendencies in empathy and prosocial behavior, including concern for the environment. Psychological and social factors, such as a sense of responsibility, sensitivity to ecological issues, and involvement in social activities, are believed to be strong drivers that shape female students' environmental awareness.

Thus, the results of this study indicate that gender is an important differentiating factor in both numeracy achievement and environmental awareness. Male students performed better in numeracy, while female students demonstrated stronger *environmental awareness*. These differences imply that teachers need to integrate learning approaches that not only emphasize cognitive aspects but also foster environmental awareness, while at the same time ensuring gender equity is taken into account.

The implications of this study indicate that the implementation of project-based learning is not only effective in enhancing students' numeracy skills but also in fostering environmental awareness through active engagement in contextual activities. The finding of differences in numeracy achievement and environmental attitudes based on gender highlights the importance for teachers to design inclusive and equitable instructional strategies. Thus, project-based learning can serve as a relevant alternative for developing both cognitive and affective competencies while minimizing gender disparities, ensuring that every student is able to grow according to their individual potential.

D. Conclusion

The PjBL model is significantly effective in enhancing students' numeracy skills (p=0.000) and environmental care attitude (p=0.002) compared to cooperative learning, directly supporting SDG 13 (Climate Action). The study also revealed significant gender disparities: males showed higher numeracy scores (p=0.005), while females demonstrated a superior environmental care attitude (p=0.000). Based on these findings, validate PjBL's efficacy in integrating contextual environmental issues, yet underscore the critical need for gender-responsive educational

strategies to ensure equitable development across both competencies, aligning with both SDG 13 and SDG 5 (Gender Equality). The PjBL is thus highly recommended for fostering the critical thinking and pro-environmental behavior necessary for addressing global climate challenges.

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