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Implementation of Project-Based Learning Using Generative AI for Designing Environmental Research Posters

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ABSTRACT

This study aims to analyze the effectiveness of Project-Based Learning (PBL) integrated with Generative Artificial Intelligence (AI) in improving students' ability to design environmental research posters. The background of this study is the limited ability of students to present research data in a clear, structured, and visually engaging manner. The research applied two approaches: an adapted Waterfall model to guide the development of AI-assisted scientific posters, and a one-group pre-test and post-test design to measure learning effectiveness. The study involved 8 students from the Plantation Management Study Program. Data were collected through pre-test and post-test, poster assessment rubrics, and student perception questionnaires. The results showed a significant improvement in student performance, with the average score increasing from 32 to 78. Statistical analysis using the Wilcoxon Signed-Rank Test indicated a significant difference between pre-test and post-test scores ($Z = -2.52$; $p = 0.012 < 0.05$), confirming the effectiveness of the implemented learning model. Poster results showed good performance, while students reported positive perceptions of AI in usefulness, creativity, and motivation. These findings indicate that Generative AI in PBL improves data presentation and scientific communication skills.

INTRODUCTION

Environmental issues such as land degradation, agricultural waste, and air pollution require not only rigorous scientific investigation but also effective communication to wider audiences. In both academic and professional settings, the ability to present research findings in a clear, visually engaging, and informative manner has become increasingly important. However, evidence indicates that science graduates often lack sufficient communication skills to meet workplace expectations, particularly in presenting research outputs. Scientific posters, as a widely used medium of research communication, have long faced challenges related to inconsistent design quality and unclear guidance for students (Pedwell et al., 2017). Moreover, although posters are commonly utilized by academics, postgraduate trainees, and students for research dissemination and professional development, their quality varies significantly, and scholarly discussions regarding their standards remain limited compared to formal publications (Pedwell et al., 2017; Peeters et al., 2025).

Project-Based Learning (PBL) has been widely acknowledged as an effective approach to enhance student engagement and develop real-world problem-solving skills. Within environmental education, PBL facilitates students in exploring authentic environmental issues and producing tangible outputs derived from field data and analysis. Research shows that PBL promotes active and meaningful learning environments, supporting both cognitive development

and environmental awareness through hands-on experiences (Yolcu, 2023). Furthermore, project-based environmental learning contributes to the development of key competencies, including problem-solving, critical thinking, and scientific practices, while also fostering positive attitudes toward environmental sustainability (Mumpuni et al., 2025). Nevertheless, despite these benefits, students often exhibit limitations in data visualization, infographic design, and the structured communication of research findings, which are essential for effective scientific dissemination.

In research-based learning contexts and competitive academic programs, such as Pekan Kreativitas Mahasiswa (PKM) and other research funding schemes, the ability to present data effectively plays a decisive role in determining the success of both proposals and research outputs. Assessment criteria in these programs typically emphasize not only the scientific rigor of the research but also the clarity of data presentation, the effectiveness of infographics, and the overall quality of visual communication. Consequently, mastering these competencies is crucial for students involved in research competitions and funding initiatives.

The emergence of Generative Artificial Intelligence (AI), including tools for text and image generation, provides substantial opportunities in education, particularly in improving students' capacity to communicate scientific information. The integration of AI in educational settings has demonstrated transformative potential by supporting academic communication skills such as writing, structuring ideas, and organizing information, while also assisting in the development of learning materials and research outputs more efficiently (Cooper, 2023; Liu et al., 2024; Shahzad et al., 2025). As a result, the ability to effectively utilize AI has become an essential digital competency in modern academic and professional environments. AI tools enable students to generate structured content, organize research findings, and design visually appealing infographics and scientific posters. Through this integration, students can enhance not only their efficiency but also higher-order thinking skills, including critical thinking, data interpretation, and visual communication.

However, the effectiveness of AI in education is strongly influenced by how it is implemented and utilized in the learning process. Without adequate guidance, students may rely on AI superficially without fully understanding its functions and limitations. Therefore, structured learning approaches such as Project-Based Learning are necessary to ensure that AI is used purposefully and responsibly. Studies have shown that AI can improve teaching effectiveness and support personalized learning when implemented appropriately (Lin, 2022; Srinivasa et al., 2022). Additionally, generative AI tools such as ChatGPT offer significant potential in enhancing academic communication, although they require critical evaluation and responsible use to address concerns related to reliability and overdependence (Cooper, 2023; Liu et al., 2024). With proper guidance, students can learn to transform raw data into meaningful visual representations, select appropriate design elements, and communicate research findings effectively. This underscores the importance of not only integrating AI into education but also ensuring its meaningful and responsible application to support scientific communication and learning outcomes.

Despite the recognized benefits of Project-Based Learning in enhancing problem-solving skills and the growing use of Generative Artificial Intelligence to support academic communication, there remains a limited number of studies that specifically examine the integration of these two approaches in environmental education. In particular, existing research has not sufficiently addressed how the combined use of PBL and Generative AI can systematically improve students' competencies in scientific poster design, data visualization, and visual communication. Furthermore, there is a lack of empirical evidence that evaluates the effectiveness of this integration using measurable learning outcomes and statistical analysis. This gap highlights the need for studies that not only implement AI-assisted learning within structured pedagogical models but also assess its impact on students' ability to transform research data into clear, informative, and visually effective scientific outputs.

Therefore, this study aims to analyze the effectiveness of integrating Project-Based Learning and Generative AI in improving students' abilities not only to design environmental research posters but also to present research data clearly through informative infographics and effective visual communication strategies. Although previous studies have highlighted the potential of Project-Based Learning in enhancing problem-solving skills and the role of Generative AI in supporting academic communication, limited research has specifically examined the integrated application of both approaches in developing students' competencies in scientific poster design and data visualization within environmental education contexts.

RESEARCH METHODS

1. Development Method: Adapted Waterfall Model

This study employed a Research and Development (R&D) approach using an adapted Waterfall model to support the implementation of Project-Based Learning integrated with Generative Artificial Intelligence. The development process began with requirement analysis to identify students' difficulties in presenting environmental research data and designing scientific posters. The Waterfall model, as part of the System Development Life Cycle (SDLC), consists of sequential stages including requirements, design, implementation, verification and maintenance, and is widely used in R&D due to its structured and systematic framework for developing learning systems (Rachma & Muhlas, 2022).

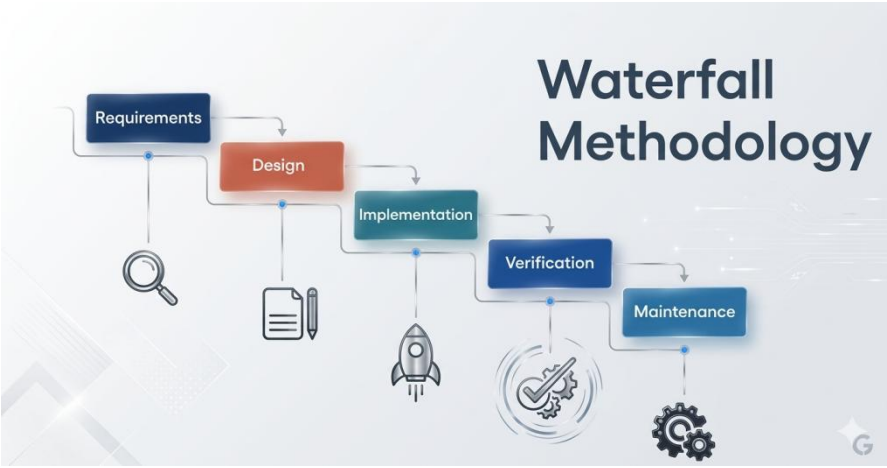

Figure 1. Waterfall model

The system design stage focused on developing structured poster components and AI-based prompt strategies to guide students in generating scientific content and visual elements. During the implementation stage, students utilized Generative AI tools such as ChatGPT for content generation and Canva for visual design. The testing stage involved lecturer evaluation and peer assessment to measure the quality of data presentation, infographic clarity, and visual communication. The maintenance stage was carried out through revisions based on feedback to improve the final poster outputs. The structured nature of the Waterfall model supports clear planning and predictable outcomes, although studies suggest that more adaptive approaches such as Agile can enhance flexibility, collaboration, and iterative improvement in development processes (Myronenko, 2025; Natarajan & Pichai, 2024).

2. Effectiveness Testing Method

To evaluate the effectiveness of the developed model, this study applied a one-group pre-test and post-test design involving 8 students selected using purposive sampling. The observed parameters included students' cognitive learning outcomes, poster quality, and perception toward AI-assisted learning. Student learning outcomes were measured using pre-test and post-test scores. Due to the small sample size (n = 8) and the non-parametric nature of the data, the

Wilcoxon Signed-Rank Test was employed to determine significant differences between pre-test and post-test results, as it is commonly used in educational research for analyzing paired data and is appropriate when the data are not normally distributed (Indah & Ahmad, 2025; Apsari et al., 2023).The statistical test is formulated as follows:

$$Z = \frac{T - \mu_T}{\sigma_T}$$

where:

T = the smaller sum of ranks from positive or negative differences

$\mu_T = \frac{n(n+1)}{4}$ = expected mean of rank sums

$\sigma_T = \sqrt{\frac{n(n+1(2n+1)}{24}}$ = standard deviation of rank sums

n = number of paired observations (excluding zero differences)

The Wilcoxon Signed-Rank Test was used to analyze the difference between pre-test and post-test scores. The test statistic was calculated using the Z approximation, where T represents the sum of ranks, μ_T is the expected mean, and σ_T is the standard deviation. The resulting Z value was used to determine the statistical significance of the observed improvement.

The hypothesis tested in this study was:

- H_0: There is no significant difference between pre-test and post-test scores
- H_1: There is a significant difference between pre-test and post-test scores

The decision rule was based on the significance value (p-value), where $p<0.05$ indicates a statistically significant improvement.

The Wilcoxon test was selected because it is suitable for small sample sizes and does not require normally distributed data, making it appropriate for this study (n = 8). Data analysis was conducted using IBM SPSS Statistics to ensure accurate and reliable computation of paired data and significance values. However, the small sample size limits the generalizability of the findings, which are primarily applicable to small-scale classroom contexts. Despite this limitation, the results provide important insights into beginner use of Generative AI, where students often rely on initial outputs without iterative refinement, leading to weak structure, low readability, and limited analytical depth. This highlights the need for guided implementation through structured approaches such as Project-Based Learning to ensure effective use of AI in improving data presentation and scientific communication skills.

RESULTS AND DISCUSSION

The development of scientific posters in this study followed an adapted Waterfall model integrated with Project-Based Learning, enabling students to systematically transform environmental data into structured and visually communicative outputs. The use of ChatGPT and Canva supported content organization, layout design, and infographic development, resulting in clearer and more informative posters. This finding reinforces that effective infographic design requires structured content, visual coherence, and alignment with communication objectives, which can be enhanced through digital and AI-supported tools (Traboco et al., 2022).

Before the implementation, students showed limited ability in structuring content, visualizing data, and utilizing digital tools for scientific communication. Their minimal experience with Generative AI also led to unstructured outputs and weak integration of visual elements. This supports previous findings that students often use Generative AI superficially without guidance, limiting its effectiveness in improving academic performance (Kim et al.,

2025). Therefore, the improvement observed in this study indicates that AI becomes effective only when integrated within a structured learning model, where students are guided to refine outputs, organize information, and develop meaningful visual communication.

Table 1. Student Poster Categories

No	Code	Topic	Category
1	S1	Quality Mapping of Gambir Resin Based on Catechin and Tannin Levels	Environmental Chemistry
2	S2	Educational Showcase of Calliandra Wood Derivatives for Renewable Energy Literacy	Renewable Energy Education
3	S3	Green Compost Innovation from Calliandra Biomass	Sustainable Agriculture
4	S4	Utilization of Calliandra Leaves as Animal Feed Protein Source	Agro-innovation
5	S5	Innovative Biomass Stove from Galvanized Plate	Renewable Technology
6	S6	Eco-Fashion Wallet from Plastic-Coir Waste	Waste Management
7	S7	Gambir Waste-Based Products for Zero Waste Awareness	Circular Economy
8	S8	Traditional Palm Oil Processing for Sustainable Agro-industry	Local Wisdom & Sustainability

Referring to Table 1, each student (S1–S8) developed posters across various environmental categories. S1 focused on environmental chemistry through the analysis of gambir resin quality, while S2 explored renewable energy education using calliandra wood derivatives. S3 and S4 addressed sustainable agriculture and agro-innovation, particularly in biomass utilization and animal feed development. Meanwhile, S5 developed a renewable technology product in the form of a biomass stove, and S6 emphasized waste management through eco-fashion innovation. S7 highlighted circular economy concepts using gambir waste, and S8 integrated local wisdom into sustainable agro-industry practices.

These results indicate that students were able to contextualize environmental issues into specific thematic categories and translate them into scientific poster formats. Despite their initially low ability, all students (S1–S8) demonstrated significant progress in organizing content, presenting data visually, and producing more structured and communicative scientific outputs.

The results indicate that all students, who initially had low ability in scientific poster design, showed significant improvement after the implementation of the AI-assisted Project-Based Learning model. Students were able to produce posters with clearer structure, improved visual quality, and more effective data presentation. Most students produced outputs in the form of infographics combined with data visualization, indicating an improvement in their ability to communicate research findings visually. The integration of AI tools enabled students to generate more organized content, enhance visual quality, and present complex data more effectively.

In addition, the diversity of poster topics demonstrates students' ability to contextualize environmental issues into practical and innovative solutions, including renewable energy, waste management, and sustainable agriculture. The posters also reflect improved creativity and clarity in delivering research messages, particularly through the use of charts, diagrams, and visual storytelling elements.

Furthermore, selected examples of student-developed posters (see Figure 2) highlight the transformation in layout structure, infographic clarity, and overall visual communication. These examples demonstrate how students were able to move from unstructured data presentation toward more systematic and professional scientific communication formats through the support of Generative AI tools.

Figure 2. Examples of Student Poster Outputs

The comparison of pre-test and post-test scores shows a significant increase in students' cognitive abilities, particularly in data interpretation and scientific communication. The mean score improved from 32 (low category) to 78 (good category), indicating a strong learning gain. To test the significance of this improvement, the Wilcoxon Signed-Rank Test was applied due to the small sample size (n = 8). The results show:

Z = -2.52

Asymp. Sig. (2-tailed) = 0.012 (< 0.05)

This indicates that there is a statistically significant difference between pre-test and post-test scores. Therefore, the implementation of AI-assisted Project-Based Learning is proven to be effective in improving student learning outcomes.

Table 2. Summary of Learning Improvement

Indicator	Pre-test Mean	Post-test Mean	Improvement
Learning Outcomes	32	78	+46

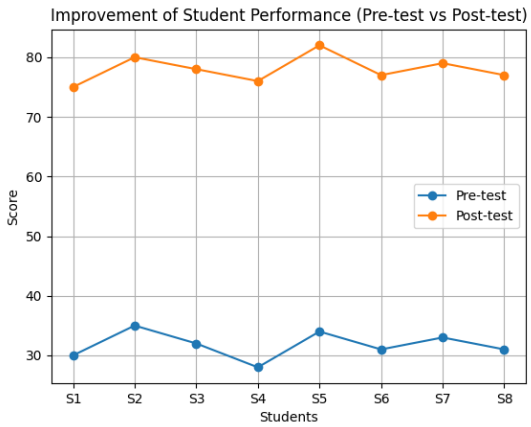

Figure 3. Improvement of Student Learning Outcomes

Figure 1 illustrates a consistent increase in scores across all students (S1–S8), indicating that the learning model has a uniform positive impact. No student experienced a decrease, which strengthens the reliability of the intervention.

The quality of student-generated posters was analyzed using five indicators: content accuracy, data presentation, infographic quality, visual design, and creativity. As shown in **Table 2**, the overall mean score reached **80**, which falls into the "good" category. This indicates that students were generally able to produce scientifically structured and visually acceptable posters after the implementation of AI-assisted Project-Based Learning.

Table 3. Poster Assessment Summary

Indicator	Mean Score	Category
Content Accuracy	82	Good
Data Presentation	79	Good
Infographic Quality	77	Good
Visual Design	83	Very Good
Creativity	81	Good
Overall Mean	**80**	**Good**

Among the indicators, visual design achieved the highest score (83), categorized as "very good," while infographic quality obtained the lowest score (77), although still within the "good" category. This indicates that students performed well in designing visually appealing posters but still need improvement in effectively presenting data through infographics.

Student perceptions toward the use of Generative AI were measured using a Likert-scale questionnaire. The results indicate a highly positive response, with an overall mean score of **4.56**.

Table 4. Student Perception Summary

Indicator	Mean Score	Interpretation
Ease of Use	4.4	High
Usefulness	4.6	Very High
Creativity Enhancement	4.7	Very High
Learning Motivation	4.5	Very High
Skill Improvement	4.6	Very High
Overall Mean	**4.56**	**Very Positive**

The findings of this study reinforce prior research indicating that the integration of Generative AI within Project-Based Learning (PBL) enhances higher-order thinking, creativity, and learning outcomes. Studies have shown that AI-supported PBL environments significantly improve students' critical thinking, problem-solving, and innovation abilities, as well as their capacity to apply knowledge in real-world contexts through dynamic and interactive learning experiences (Tariq, 2025; Osman et al., 2025; Wan, 2025; Medina-López & Jiménez-Partearroyo, 2025).

Furthermore, the high perception scores indicate that students view AI as a useful and accessible tool, highlighting the importance of technology acceptance in learning effectiveness. Previous studies show that students generally perceive generative AI as helpful for idea generation, research, and personalized learning, although its effectiveness depends on structured and purposeful use (Pesovski et al., 2024; Cummings et al., 2024; Hou et al., 2024).

The results also show that AI integration enhances visual communication skills, which are essential in academic contexts such as research dissemination, scientific poster presentations, and competitive research programs. In this case, students demonstrated improved ability to organize data, select appropriate visuals, and deliver clear research messages. However, the relatively lower score in infographic quality suggests that students still require further training in

advanced data visualization techniques. This indicates that while AI provides strong support, pedagogical guidance remains essential to maximize learning outcomes.

Overall, this study supports the argument that AI-assisted Project-Based Learning is an effective approach to improving students' data presentation skills, creativity, and scientific communication abilities. The findings can be applied in similar vocational and higher education contexts, particularly in courses that require the production of visual research outputs.

CONCLUSION

This study demonstrates that the implementation of Project-Based Learning integrated with Generative Artificial Intelligence is effective in improving students' ability to design environmental research posters and present research data clearly and informatively. The results show a significant improvement between pre-test and post-test scores, indicating enhanced data interpretation, visual communication, and infographic development. In addition, the quality of student-produced posters reflects better content organization, more effective visual use, and clearer delivery of research messages.

These findings indicate that integrating Generative AI in project-based learning strengthens both cognitive and practical competencies in transforming research data into visual outputs. The main contribution of this study lies in demonstrating that AI-assisted Project-Based Learning provides an effective approach to bridge the gap between research skills and visual communication in applied learning contexts. Practically, educators are encouraged to integrate Generative AI tools to support data visualization and scientific communication skills, while future research should involve larger samples and examine long-term impacts across different disciplines.

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