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Enhancing Botanical Literacy Through Project-Based Learning with Botanipedia: A Study on Plant Diversity and Classification

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ABSTRACT

Botanical literacy among students remains relatively low, as reflected in recent studies highlighting students' limited understanding and appreciation of plant diversity and its essential role in ecosystems and human life. This condition underscores the urgency to implement innovative learning strategies to improve students' botanical literacy. This study aims to analyze the effect of the Project-Based Learning (PjBL) model assisted by Botanipedia media on students' botanical literacy in plant diversity and classification. As part of biological literacy, botanical literacy includes knowledge, inquiry skills, and the ability to connect plant concepts to real-life contexts. This research applied a quasi-experimental design with a nonequivalent control group. The sample consisted of two Grade X classes at SMA Negeri 2 Tasikmalaya, selected through purposive sampling. Class X-1 (experimental group) was taught using PjBL assisted by Botanipedia, while class X-3 (control group) was taught using PjBL without additional media. Botanical literacy was measured using a 15-item multiple-choice test developed based on Uno and Bybee's framework. Data were analyzed using Quade Rank Analysis of Covariance. The results showed a significant improvement in the experimental group compared to the control group ($p = 0.031$, $p < 0.05$). The integration of Botanipedia enhanced students' botanical literacy across all indicators. These findings support using interactive media to strengthen botanical literacy through project-based learning.

Keywords: Botanipedia, Botany literacy, Project based learning

Introduction

Indonesia is one of the countries with very high biodiversity, including the abundance of species and ecosystems (Irawanto, 2023). Based on 2017 data, it was recorded that the number of plant species in Indonesia reached 31,750 species (Retnowati et al., 2019). Plants have a crucial role in maintaining the balance of the ecosystem and sustaining life on earth; both humans and animals depend on the existence of plants for their survival (Irawanto, 2023). However, the sustainability of plants is increasingly threatened due to various factors such as deforestation and climate change. It is estimated that around 240 plant species have been categorized as rare due to overexploitation, hunting, and illegal trade (Kusmana & Hikmat, 2015). Therefore, understanding plants is necessary, especially for future generations. In education, the younger generation needs to be equipped with in-depth botanical literacy, which encompasses not only the understanding of botanical concepts but also awareness of biodiversity and the important role of plants in life. With a good level of botanical literacy, students are expected to appreciate and play an active role in efforts to preserve plant diversity for the sake of environmental sustainability in the future.

Botanical literacy is part of biological literacy that includes understanding, interest, inquiry skills, and the ability to apply this knowledge in everyday life (Uno, 2009). According to Uno and Bybee (1993), botanical literacy can be developed through various levels, from introducing basic terms to understanding more complex botanical concepts, such as the interaction of plants with the environment and human life. A person's level of botanical literacy can be assessed from direct experience in planting, observing, and identifying plants around them (Sari et al., 2018). In addition, botanical literacy also plays a role in developing critical thinking skills, especially in classifying plants and solving botany-related problems (Rizkamariana et al., 2019). However, Sari et al. (2023) found that students' critical thinking, analysis, and evaluation skills related to botanical literacy in schools remain relatively low. This shows that it is not enough for students to memorize information about botany. However, the ability to relate plants to various other disciplines is also needed to obtain a more comprehensive level of botanical literacy.

Based on observations made through distributing tests to students at SMA Negeri 2 Tasikmalaya, it was found that they had mastered botanical literacy in the Lower Order Thinking Skill (LOTS) category of questions. However, their botanical literacy is still relatively low when faced with High Order Thinking Skill (HOTS) category questions. This shows that even though students have understood the factual aspects of botanical literacy, they do not yet have an optimal ability to think critically or apply botanical concepts in problem-solving. One of the factors causing this weak botanical literacy is the lack of use of innovative learning methods and the lack of utilization of technology in the learning process.

To overcome these obstacles, a more effective learning model is needed so students can actively explore and discover plant knowledge. One of the learning models that can be applied is the Project-Based Learning (PjBL) model, which is integrated with Botanipedia media as a learning resource. PjBL is a student-centered learning model; in the process, students can develop ideas and realize them through projects. According to Thomas (2000), PjBL is a learning model involving complex projects in all learning processes. PjBL learning is oriented towards problem solving, creating a more meaningful and enjoyable learning experience for students (Anggelia et al, 2022). This model aims to increase learners' creativity in completing tasks that have proven effective in improving botanical and science literacy (Sari et al., 2021). With an experiential approach, learners can explore, experiment, and understand scientific concepts more deeply, thus improving their botanical literacy and retention of material (Farhin et al., 2023). Moreover, using interesting media, such as the botanipedia website, as a learning resource can facilitate a varied and interactive learning process. Website-based media can reduce the monotonous learning atmosphere and create a more dynamic and enjoyable experience (Darussalam, 2015). This website provides easy access for students to understand botanical concepts through comprehensive and engaging information, thereby enhancing botanical literacy among students.

However, previous research conducted by Sari et al. (2018) stated that applying the PjBL model alone has not significantly improved botanical literacy skills. This finding is consistent with insights from a recent review by Permana et al. (2025), which emphasized that traditional media—such as textbooks—are no longer sufficient in addressing biodiversity education. Their analysis using Scopus AI highlights the importance of emerging tools such as augmented reality, virtual field trips, and gamified platforms to foster engagement and support higher-order thinking in botanical learning. In addition, a bibliometric study by Husamah et al. (2025) revealed that although global research on botanical literacy has increased significantly over the last decade, contributions from countries like Indonesia remain minimal. They also identified significant barriers such as low student interest, lack of engaging media, and ineffective instructional strategies. The study recommends the integration of inquiry-based and technology-enhanced learning to strengthen botanical literacy development.

While project-based learning has been widely applied in biology education, its integration with digital platforms designed explicitly for botanical content, such as Botanipedia, remains underexplored. Botanipedia is a web-based learning resource that presents detailed images and descriptions of various plant species, designed to help students understand botanical concepts more deeply through a rich, visual, and context-based approach. Its accessible, structured, and interactive features address the common limitations of project-only learning in taxonomy by supporting students' analytical skills and motivation to explore plant diversity meaningfully. Until now, no study has systematically evaluated how the synergy between PjBL and web-based media like Botanipedia affects students' botanical literacy, particularly in the context of plant diversity and classification. This gap highlights the need for research that innovatively combines active learning models with digital content tailored to plant science. Therefore, this research was conducted to find out how applying the PjBL model assisted by Botanipedia media influences the improvement of students' botanical literacy.

Methods

This research applied a quantitative approach using a quasi-experimental method with a nonequivalent control group design. The study population comprised 370 grade X students at SMA Negeri 2 Tasikmalaya. The sample was selected using a purposive sampling technique, based on the similarity in students' activeness levels as determined from interviews with biology teachers. Two classes, X-1 and X-3, with comparable characteristics, were chosen; class X-1 served as the experimental group receiving PjBL assisted by Botanipedia media, while class X-3 functioned as the control group receiving only PjBL without additional media.

The research instrument to measure botanical literacy skills consisted of 15 multiple-choice items, developed based on the theoretical framework by Uno and Bybee (1994), which includes four levels of botanical literacy: nominal, functional, structural, and multidimensional. Each level was represented by 3 to 4 items. The nominal level focused on students' ability to recognize and recall basic botanical terms (e.g., "Which of the following is classified as a non-vascular plant?"). The functional level assessed the ability to apply fundamental knowledge in familiar contexts (e.g., "What plant structure is primarily responsible for photosynthesis?"). The structural level evaluated understanding of the relationships between botanical concepts (e.g., "How are ferns and flowering plants similar in their reproductive structures?"). Finally, the multidimensional level measured students' ability to connect botanical knowledge with social or environmental issues (e.g., "Why is conserving plant diversity important for sustainable food systems?"). Biology education experts reviewed these items to ensure content validity and alignment with the intended indicators. Before conducting the field trial, the instrument underwent construct validation by biology expert lecturers to ensure the content and conceptual appropriateness. Following this expert validation, a pilot test was conducted to examine the instrument's validity and reliability using SPSS software, ensuring measurement accuracy and feasibility.

Botanical literacy was assessed quantitatively through pre-tests and post-tests administered to the experimental and control classes. Students also created learning products to demonstrate their understanding as part of the project-based learning process. In this study, the typical products developed by student groups included infographic posters of plant classification, digital flipbooks, herbarium portfolios, vlogs, and YouTube videos—each illustrating plant characteristics, taxonomy, and ecological functions. The product format was not predetermined; each group was free to propose their preferred format, provided it remained relevant to the topic and was approved by the teacher. Although these products were not used as direct assessment tools, they served as meaningful components of the learning experience. These creative outputs fostered student engagement, encouraged contextual exploration of botanical concepts, and enhanced conceptual understanding—particularly in the experimental group utilizing Botanipedia as a digital learning aid.

The intervention was conducted over two 90-minute learning sessions. The research procedure consisted of three main stages: (1) pretest administration, (2) implementation of project-based learning (PjBL) in both experimental and control groups, and (3) posttest administration. The experimental group was taught using the PjBL model integrated with Botanipedia, a web-based learning media containing botanical images, descriptions, and classification information. The control group received instruction using the standard PjBL model with textbook-based materials and teacher explanations. Each group followed the six phases of PjBL as proposed by Thomas (2000), adapted for two learning sessions. Table 1 below outlines how the learning activities were conducted in both groups and how Botanipedia was integrated explicitly in the experimental class. In the first stage, both groups were given a 15-item multiple-choice pretest to assess their initial botanical literacy levels based on four indicators (nominal, functional, structural, and multidimensional). During the second stage, both classes received instruction using the PjBL model, but with different learning resources:

Table 1. Implementation of PjBL stages in experimental and control groups

PjBL Phase	Learning Activities in Experimental Group (with Botanipedia)	Learning Activities in Control Group (without Botanipedia)
1. Start with Essential Question	Teacher stimulates students with a contextual problem about plant classification. Students formulate key questions with guidance.	Same activity, but using textbook examples and printed materials.
2. Design Project	Students collaborate to plan their project using Botanipedia as a primary information source for plant data.	Students design project plans using textbook-based content and worksheets.
3. Create Schedule	Students determine activity timelines to complete their projects.	Same activity.
4. Monitor the Student and the Project	Students document project progress and send updates (photos/videos) via WhatsApp. They use Botanipedia for ongoing research.	Students report progress orally or via worksheet, without using digital botanical references.
5. Assess the Outcome	Students present products (e.g., infographics, flipbooks, videos).	Students present products (similar formats)
6. Evaluate the Experience	Students and teacher reflect on the project and learning experience, including how Botanipedia supported their understanding.	Students reflect on learning outcomes without digital media integration.

Data analysis included descriptive statistics and inferential testing to compare pretest and posttest results between groups. Before inferential analysis, assumption tests for parametric analysis (normality and homogeneity) were conducted; however, since these assumptions were not met, the nonparametric Quade's Rank Analysis of Covariance (Quade's ANCOVA) was employed to test the significance of differences in posttest scores while controlling for pretest scores. The analysis was performed using SPSS version 24 for Windows, with a significance level set at $\alpha = 0.05$.

Results and Discussion

The improvement in students' botanical literacy skills in both the experimental and control classes is summarized in Table 1. The data show that the experimental class, which received Project-Based Learning (PjBL) assisted by Botanipedia media, experienced a substantially greater increase in mean scores compared to the control class that received PjBL without the additional media. Specifically, the experimental class improved by 26.67 points on average (an increase of approximately 65.22%), whereas the control class improved by 8.66 points (about 17.09%). This notable difference indicates that integrating Botanipedia media as a supplementary tool effectively enhances students' botanical literacy beyond the effect of PjBL alone.

Table 2. Mean pretest, posttest, and difference scores of experimental and control groups

Class	N	Pretest		Posttest		Difference Mean
		Mean	SD	Mean	SD	
Experiment	30	40.89	19.471	67.56	25.841	26.67
Control	30	50.67	19.089	59.33	23.974	8.66

Table 2 presents the average pretest and posttest scores and their standard deviations for both groups. Although the control class began with a higher initial mean score (50.67) compared to the experimental class (40.89), the experimental group's posttest mean score (67.56) exceeded that of the control group (59.33). The greater improvement observed in the experimental group suggests that using Botanipedia media within the PjBL framework effectively supports and accelerates the development of botanical literacy skills.

To further examine whether the observed differences in botanical literacy outcomes between the experimental and control groups were statistically significant after controlling for initial differences in pretest scores, a Quade Rank Analysis of Covariance (ANCOVA) was conducted. This nonparametric approach was chosen because it violated assumptions required for parametric ANCOVA, including normality and homogeneity of variances. The analysis used SPSS version 24, with a significance level set at $\alpha = 0.05$. The results of the Quade ANCOVA are summarized in Table 3.

Table 3. Results of *quade rank analysis of covariance* test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1209.692	1	1209.692	4.899	.031
Within Groups	14320.795	58	246.910		
Total	15530.487	59			

Table 3 shows that the Quade ANCOVA yielded a significant result, with an F-value of 4.899 and a p-value of 0.031 ($p < 0.05$). This indicates that, after adjusting for pretest scores, there was a statistically significant difference in botanical literacy posttest scores between students who learned with the PjBL model assisted by Botanipedia media and those who experienced PjBL without it. These findings support the conclusion that integrating interactive media such as Botanipedia into project-based learning can positively and meaningfully enhance students' botanical literacy.

Several factors can explain the significant increase in the experimental class. Botanipedia media, as a learning resource, allowed students to explore botanical literacy concepts interactively. This media provides more visual information, so students can more easily understand the characteristics of plants based on the classification studied. The results of research conducted by Uyuni et al (2024) prove the effectiveness and efficiency of using website-based learning media in plant anatomy courses. Web-based media can support learning because it contains images and text that can represent the perception and understanding of the concept of students on the biological objects observed (Diana et al., 2024). In addition, multimedia-based learning can deepen learners' understanding by simultaneously combining visual and text elements (Imran et al., 2015). These findings support the current study's result, where the integration of visual-rich, web-based media significantly improved students' botanical literacy outcomes, particularly in plant morphology and classification indicators.

Second, in the PjBL learning process, students in the experimental class were more active in constructing their knowledge through the project. According to Wu (2024), active involvement in hands-on exploration can deepen learners' understanding. In addition, according to Sulisetijono et al (2024), botany learning strategies should focus on exploring plants in the surrounding environment. The information accessed from Botanipedia during the planning and execution of student projects supported the development of botanical literacy by encouraging deeper inquiry into plant concepts. Botanipedia media is used in planning and implementing projects to find relevant information, thus increasing their active involvement and understanding of the material being studied. This aligns with Wu (2024) and extends the literature by demonstrating that media-supported PjBL fosters engagement and results in measurable improvements in students' botanical literacy, as reflected in increased post-test scores across all four indicators (see Figure 1).

Figure 1 compares the mean scores of the experimental and control classes for each botanical literacy indicator. The results indicate that the experimental class consistently outperformed the control class across all four indicators: nominal, functional, structural, and multidimensional. The nominal level, which emphasizes recognizing basic botanical terms and concepts, achieved the highest average score in both classes. In contrast, the multidimensional level, which involves integrating plant knowledge with broader environmental and societal issues, had the lowest. Despite this decline in difficulty level, the experimental group still showed a higher mean score at every level, suggesting that integrating Botanipedia in the PjBL model significantly impacted students' botanical literacy. This reinforces that the intervention with digital media was beneficial at the surface (LOTS) level and in supporting deeper understanding and higher-order thinking (Fitriasih et al., 2024; Musfiroh et al., 2024).

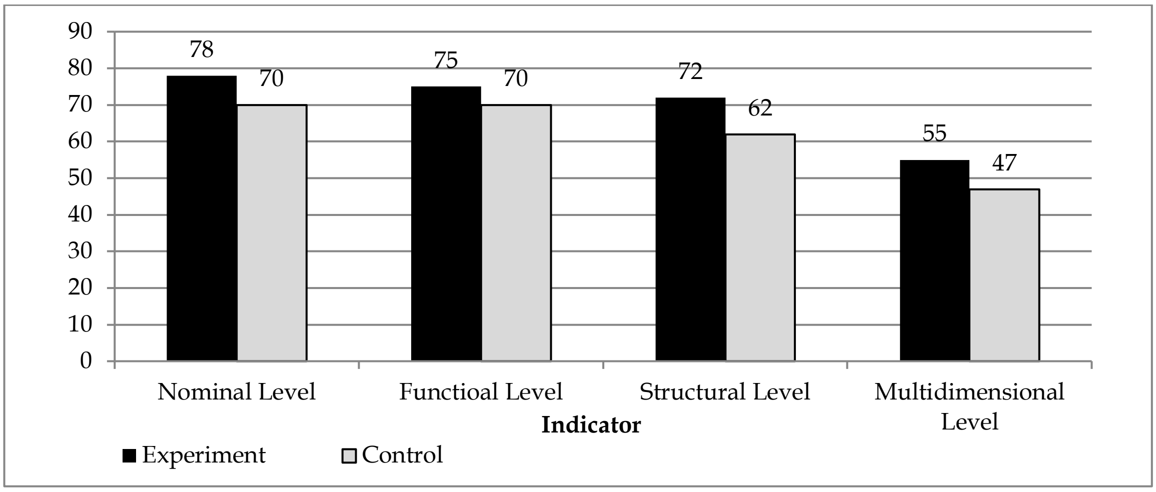

Figure 1. Average botanical literacy indicator

Different features of the Botanipedia media supported each indicator of botanical literacy. At the nominal level, students benefited from the visual glossary, clear labeling of plant parts, and high-resolution images that helped them recognize basic terminology and morphology (Link-Pérez et al., 2010; Purnama et al., 2020). Functional literacy was supported through contextual descriptions, such as plant benefits and ecological roles, which helped students relate plant knowledge to real-life applications (Arif et al., 2025). For the structural level, comparison tools and classification guides within Botanipedia enabled students to analyze relationships among plant taxa based on morphological similarities and differences (Pongsophon & Jituafua, 2021). Meanwhile, the multidimensional level was stimulated through content linking plants to environmental sustainability and conservation, encouraging students to make interdisciplinary connections and develop critical perspectives on biodiversity (Coşkunserçe, 2024). These targeted features made it easier for students to map digital content to cognitive processes required at each literacy level.

In the experimental class, the use of Botanipedia was deeply embedded in the PjBL phases from project design and data gathering to analysis and product presentation. Students used Botanipedia to identify species around their school or home environments, verify their classification, and incorporate this information into products such as infographic posters and digital flipbooks. This hands-on engagement allowed students to merge theoretical understanding with field-based exploration. For example, in designing visual posters, students compared leaf arrangements, floral structures, and stem types using Botanipedia's reference images, increasing their outputs' accuracy and depth. Asare & Parker (2022) highlighted the power of digital media to enhance learning engagement and comprehension in biology. This study builds on that by showing that when integrated into PjBL, media like Botanipedia can directly support the development of botanical literacy both conceptually and procedurally through structured, stage-specific interventions.

Meanwhile, students in the control class who only used the PjBL method without additional media faced obstacles in understanding botanical concepts. Limited learning resources made them dependent on textbooks or conventional teacher explanations. The lack of clear visualization to support the material causes their understanding of the structure and characteristics of plants to be more limited. Rifai et al. (2020) mentioned that learning that relies less on visual media can hinder conceptual understanding in students. This can cause the control class to obtain lower scores than the experimental class. Consistent with this, the lower posttest results in the control group confirm that conventional resources are less effective in supporting complex conceptual acquisition in botany.

Although the Botanipedia media contributed positively to improving botanical literacy, the results of this study showed that learners' performance declined on more complex indicators. The highest scores were obtained at the nominal level, focusing on recognizing basic botanical terms and concepts. In contrast, the lowest scores appeared at the multidimensional level, which requires higher-order thinking such as analyzing, evaluating, and applying botanical knowledge in broader social and environmental contexts. According to Uno & Bybee (1994), botanical literacy involves more than factual knowledge. It includes the ability to understand and apply concepts critically. This study revealed that while students could successfully identify and recall plant-related information, their ability to make cross-contextual connections or solve real-world botanical problems was still developing.

Several factors may explain this limitation. First, the short duration of the intervention, only two learning sessions, may have limited the time available for students to engage deeply in reflective analysis and interdisciplinary application. Second, while Botanipedia provided rich visual and textual information to support concept understanding, its use was primarily focused on supporting project construction rather than fostering analytical dialogue or argumentation. As a result, most students used the media to identify morphological features and classify plants. However, they lacked structured opportunities to interpret ecological significance or social implications, key aspects of multidimensional literacy. To address this, future learning designs should incorporate extended time for exploration, guided metacognitive scaffolding, and critical discussions to fully support students' development across all dimensions of botanical literacy (Arif et al., 2025; Pantiwati et al., 2023; Pierce & Gilles, 2020).

This study contributes to the growing body of evidence on technology-enhanced PjBL in science education. Specifically, it highlights the potential of targeted media like Botanipedia to improve learning outcomes in underexplored domains such as botanical literacy. Botanipedia is a flexible, web-based platform, so this model holds strong potential for scalability and adaptation in various educational settings. It can be integrated into different regional curricula, including in rural or resource-limited schools, as long as basic digital access is available. Its visual and structured content can support diverse student populations, regardless of prior knowledge levels, and can be localized by incorporating regional plant species to increase relevance and engagement. This suggests that the combined approach of PjBL and Botanipedia is practical, but adaptable and inclusive for broader implementation.

Conclusion

This study concludes that integrating the PjBL with Botanipedia media significantly enhances students' botanical literacy, as reflected in the experimental class's higher mean gain score and statistically significant difference ($p = 0.031$). The improvement was most notable in the nominal and functional indicators. In contrast, performance on structural and multidimensional indicators requiring higher-order thinking, such as analysis and contextual application, remained relatively limited. The novelty of this study lies in the contextual and structured integration of Botanipedia, a web-based digital resource specifically designed for plant science, into each stage of PjBL, which has not been systematically examined in previous botanical literacy research. These findings suggest practical implications for educators: incorporating interactive and contextualized digital tools like Botanipedia can improve student engagement and foundational botanical understanding. Moreover, due to its adaptability and accessibility, the intervention shows potential for scalable application across diverse student populations and educational environments, especially when aligned with local biodiversity themes. Future research should explore broader implementation and enhance digital features to strengthen students' analytical reasoning and support deeper conceptual transfer in plant science learning.

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