RESEARCH ARTICLE

Enhancing students' information literacy through project-based learning: A mini research on plant morphology identification

Neni Murniati[a,1,*], Y. Yennita[a,2], Dinda Triski Oktaria Ha[a,3], R. Riyanto[b,4]

[a] Department of Biology Education, Faculty of Teacher Training and Education, Universitas Bengkulu, Jl. WR Supratman, Kandang Limun, Bengkulu 38271, Indonesia

[b] Department of Biology Education, Faculty of Exact and Sport, Universitas Insan Budi Utomo Malang, Jl. Citandui Number 46, Purwantoro, Blimbing, Malang, East Java 65126, Indonesia

[1]nenimurniati@unib.ac.id*; [2]yennita@unib.ac.id; [3]dindatriskioktaria@gmail.com; [4]riyanto@uibu.ac.id

Abstract: Plant morphology courses develop students' understanding of plant structures and identification skills through mini-research activities. Effective species identification requires a literature review and the ability to find, evaluate, and use relevant information. This qualitative study examines students' information literacy skills in completing plant identification projects using Project-Based Learning (PjBL). The research involved 63 biology education students enrolled in a plant morphology course. Data were collected through questionnaires assessing information literacy skills and portfolios documenting mini-research reports. Descriptive analysis revealed that the PjBL model enhanced students' information literacy skills, with 65% classified as "in progress," indicating ongoing development. Students successfully identified various plant types, including ornamental plants, medicinal plants, shade trees, and fruit and vegetable plants. The ability to locate relevant information was a key factor in improving literacy skills. Additionally, collaboration, interest, and the use of technology supported students' literacy development. These findings suggest that integrating PjBL into plant morphology courses can foster essential information literacy competencies.

Keywords: information literacy; plant morphology identification; PjBL

For correspondence:
nenimurniati@unib.ac.id

Article history:
Received: 3 January 2025
Revised: 24 February 2025
Accepted: 3 March 2025
Published: 24 March 2025

10.22219/jpbi.v11i1.38918

p-ISSN: 2442-3750
e-ISSN: 2537-6204

How to cite:
Murniati, N., Yennita, Y., Ha, D. T. O., & Riyanto, R. (2025). Enhancing students' information literacy through project-based learning: A mini research on plant morphology identification. *JPBI (Jurnal Pendidikan Biologi Indonesia), 11*(1), 378-387 https://doi.org/10.22219/jpbi.v11i1.38918

Introduction

The Assessment and Teaching of 21st Century Skills (ATC21S) framework categorizes essential 21st-century skills into four domains: ways of thinking, ways of working, tools for working, and skills for living in the world. These skills significantly influence students' ability to acquire other competencies necessary for success in the modern era. Among these, information literacy is classified as a crucial life skill in a global context (Akour & Alenezi, 2022; Care & Kim, 2018; Chu et al., 2011; Griffin et al., 2012; Tachie-Donkor & Ezema, 2023). The rapid advancements in technology, particularly in the Industrial Revolution 4.0, have introduced digitalization across all sectors, including education. Technology is no longer limited to skill transmission; it now plays a critical role in assessing competencies and shaping future career prospects (Aghazadeh, 2019; Aguilar & Turmo, 2019; Marty et al., 2013). To adapt to these changes, teaching methodologies in higher education must evolve, ensuring students are equipped with essential skills such as information literacy. This can be achieved through learning models that actively engage students in utilizing diverse information sources.

Information literacy is fundamental for students as it enhances their ability to search for, evaluate, and utilize information effectively. It also fosters critical thinking, decision-making, analytical reasoning, and writing proficiency (Akour & Alenezi, 2022; Karimi et al., 2015).. Moreover, mastering information literacy can significantly impact students' future careers (Saenab et al., 2022). This skill set is developed through competencies such as searching for information, identifying reliable sources, and effectively using the retrieved data (Shopova, 2014). In the context of Industrial Revolution 4.0, the ability to access, evaluate,

and apply information efficiently has become a core academic and professional requirement. Information literacy involves identifying, retrieving, and managing information for problem-solving purposes (Schiffl, 2020). It also plays a key role in research by enabling students to synthesize and apply relevant knowledge. Studies have highlighted the primary indicators of information literacy, including searching for information, discerning credible sources, and effectively utilizing information (Schiffl, 2020; Shao & Purpur, 2016; Shopova, 2014).

Sources of information vary widely, including libraries, books, academic journals, and digital databases. The transition toward digital libraries and online repositories has made information more accessible, eliminating the need for physical library visits (Tachie-Donkor & Ezema, 2023). These digital resources continue to evolve, making information retrieval more efficient (Pinto et al., 2024). However, merely accessing information is not sufficient—students must also develop the ability to critically evaluate and apply the acquired knowledge (Klucevsek & Brungard, 2016). Effective information management requires retrieving, analyzing, and organizing data for practical use (Saleh et al., 2017).

For biology education students, particularly those at Bengkulu University, information literacy is vital. However, there is currently a lack of empirical data on the information literacy skills of prospective biology educators. It is essential for educational policymakers to assess students' competencies in this area to develop effective strategies for enhancing information literacy in learning. Strengthening information literacy skills will also help future teachers create engaging and effective learning experiences for their students.

A lack of information literacy hampers students' ability to process information and conduct research, particularly in plant morphology identification. This deficiency also affects their ability to apply correct identification techniques when distinguishing plant species. Information literacy is essential for conducting research, solving problems, and making informed decisions. Thus, it should be integrated into all aspects of learning, including coursework, research assignments, and problem-solving activities (Hackman, 2012; Kim et al., 2019; Martín Erro et al., 2022). The Plant Morphology course is a fundamental component of biology education. It involves both theoretical exploration and practical observation, enabling students to identify plant species based on their morphological characteristics (Yan et al., 2021). This process requires students to search for and utilize relevant scientific sources to examine plant features such as leaves, stems, roots, flowers, fruits, and seeds. These activities constitute mini-research projects, which are conducted through Project-Based Learning (PjBL) and culminate in the creation of a plant herbarium. To successfully complete these tasks, students need to develop strong information literacy skills that enable them to navigate both conceptual and practical aspects of plant morphology.

One of the most effective pedagogical approaches for enhancing information literacy is Project-Based Learning (PjBL). This method integrates collaborative and inquiry-based projects into the learning process, encouraging students to actively engage in problem-solving and research. PjBL is a student-centered approach that fosters critical thinking, decision-making, and hands-on learning (Raycheva et al., 2017; Ruiz-Rosa et al., 2021; Tong et al., 2020). PjBL as an innovative learning strategy designed to help students tackle complex, real-world problems through research and investigation (Holmes & Hwang, 2016; Kokotsaki et al., 2016; Muhdhar et al., 2021). The George Lucas Educational Foundation outlines six key steps in PjBL: (1) Posing essential questions to guide inquiry; (2) Designing a project plan; (3) Developing an activity schedule; (4) Monitoring student progress; (5) Assessing student performance; (6) Reflecting on learning experiences (GLEF, 2024).

Implementing Project-Based Learning (PjBL) can significantly enhance the quality of education, particularly in plant morphology courses. It also aligns with technological advancements, reinforcing the need for strong information literacy skills in research and problem-solving. This study aims to examine the information literacy competencies of biology education students, particularly in the context of Project-Based Learning (PjBL) and plant morphology identification. The findings of this research will provide insights into students' ability to search for and retrieve information, evaluate sources, and apply knowledge effectively. The results will also contribute to the development of more effective teaching strategies for enhancing information literacy in biology education.

Method

This study employs a descriptive research design aimed at enhancing the quality of learning through project-based learning (PjBL) mini-research on plant morphological identification. The primary objective is to describe students' information literacy skills. This research was conducted at Bengkulu University, located on Supratman Street, Kandang Limun, Bengkulu City, Indonesia. The study took place over six months, from March to May 2024. The primary research activities were carried out at the Joint Building (GB 3) of Bengkulu University. The population of this study comprised students enrolled in the Biology Education Study Program during the even semester of the 2023/2024 academic year. The sample consisted of 63 students who were actively participating in the *Plant Morphology* course. These students were divided into two sections: Biology Education 2A and Biology Education 2B. A purposive sampling

technique was employed to ensure the selection of a representative sample from the biology education cohort.

The primary research instrument used to assess students' information literacy skills was an information literacy rubric adapted from the Colorado Educational Media Association (CEMA, 1996) *Information Model Guide*. Data collection was carried out with the assistance of two observers over the course of seven meetings, each of which focused on different morphological aspects of plants, including leaves, stems, roots, flowers, fruits, and seeds. The observation aimed to evaluate the implementation of project-based learning and its impact on students' information literacy. The information literacy rubric consisted of five key indicators: (1) Students as knowledge seekers; (2) Students as quality producers; (3) Students as independent learners; (4) Students as group contributors; and (5) Students as responsible information users

Additionally, the structured syntax of the Project-Based Learning (PjBL) model implemented in this study included:

1. Formulating fundamental questions
2. Planning the project
3. Developing a project schedule
4. Monitoring and evaluating student progress and project development
5. Presenting project outcomes
6. Conducting final project evaluation

The data on students' information literacy skills were analyzed using descriptive quantitative methods. The average information literacy scores over six meetings were calculated and categorized based on predetermined classification criteria (as outlined in Table 1).

Table 1. Information literacy assessment indicators

Score	Category
2.0- 2.7	In Progress
2.8-3.1	Essential
3.2-3.5	Proficient
3.6-4,0	Advanced

Results and Discussion

Learning outcomes of the project-based learning

Implementing Project-Based Learning (PjBL) in plant morphology instruction has resulted in the production of various herbarium specimens, covering diverse plant categories such as ornamental plants, medicinal plants, shade trees, fruit plants, and vegetable plants. Examples of herbarium specimens produced by students include *Apium graveolens* (Celery), *Hibiscus rosa-sinensis* (Hibiscus), *Brassica oleracea var. alboglabra* (Kailan), *Alpina galanga* (Galangal), *Acacia auriculiformis* (Acacia), *Melaleuca leucadendra* (Eucalyptus), *Terminalia mantaly* (Madagascar Almond), *Monstera adansonii* (Swiss Cheese Plant), *Ocimum basilicum* (Basil), *Mussaenda pubescens* (Nusa Indah Putih), *Vitis vinifera* (Grape), and *Araucaria heterophylla* (Norfolk Cypress) (Figure 1).

a. *Apium graveolens* (Celery)

b. *Hibiscus rosa-sinensis* (Hibiscus)

c. *Brassica oleracea var. alboglabra* (Kailan)

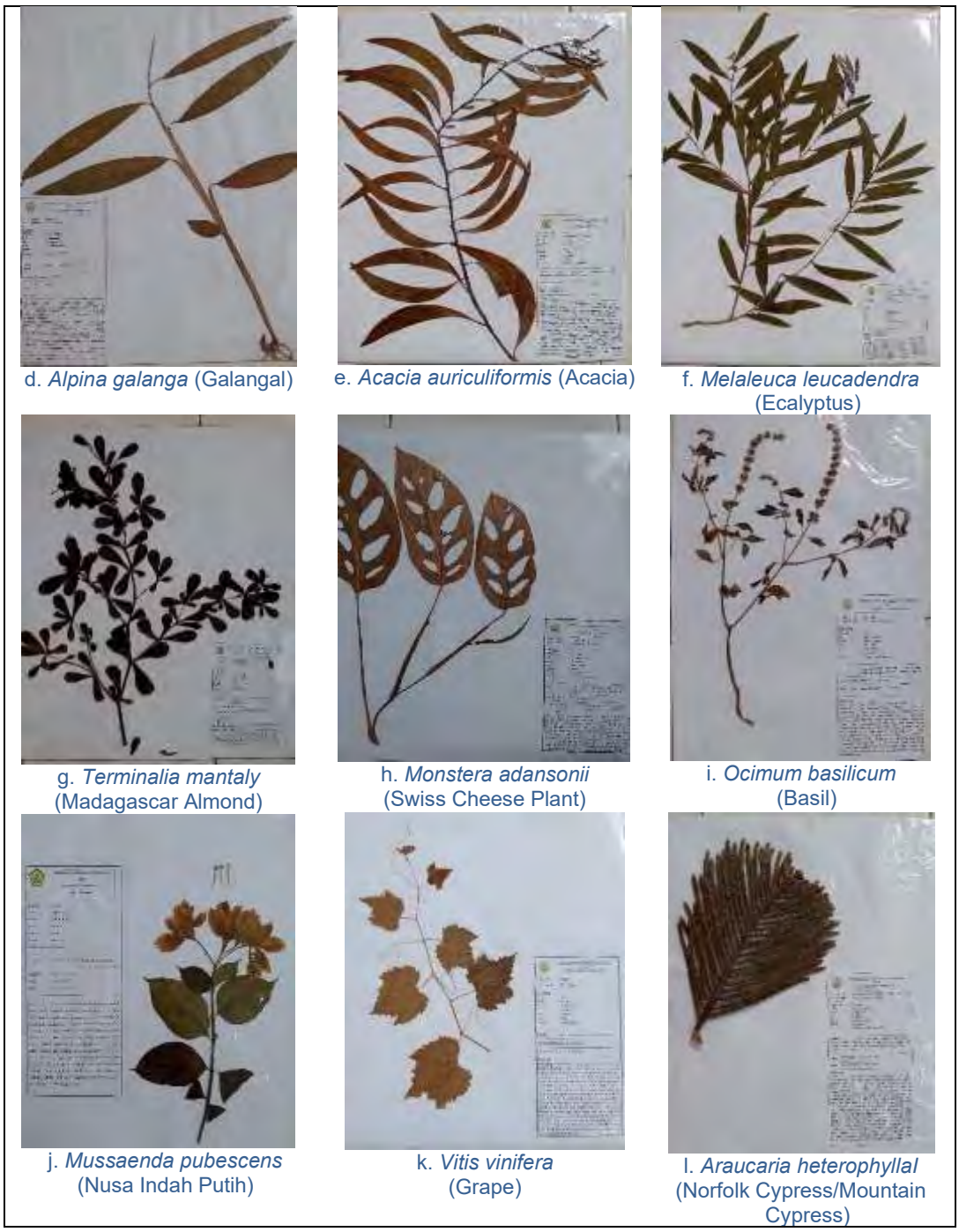

Figure 1. Student herbarium products in plant morphology course

PjBL is an instructional approach that emphasizes the development of students' competencies in producing a tangible product aligned with course learning objectives. Through PjBL, students engage in knowledge exploration, conduct mini-research on plant morphology, and create herbarium collections. The learning process begins with students selecting plant specimens, identifying their morphological features, and documenting their findings. This process involves planning, instrument preparation, plant inventory, data collection, and morphological analysis of various plant structures, including leaves, stems, roots, flowers, fruits, and seeds. The final product of this learning approach is the herbarium, which serves as evidence of student engagement in scientific investigation.

PjBL projects involve complex tasks that require students to formulate research questions, solve problems, make decisions, conduct investigations, and work independently (Isabekov & Sadyrova, 2018; Kartini et al., 2021; Kokotsaki et al., 2016).The selection of PjBL as a learning strategy aligns with its

capacity to engage students in meaningful projects that contribute to environmental sustainability (Stokes & Harmer, 2018). Studies indicate that PjBL fosters student engagement, enhances creativity and promotes problem-solving abilities (Melinda & Zainil, 2023). Lecturers play a crucial role as facilitators, evaluating students' project outputs based on predefined criteria (Bielik et al., 2022). PjBL has also enhanced motivation, collaboration, critical thinking, and creativity (Li et al., 2020; Sasson et al., 2018; Terrón-López et al., 2017). Additionally, PjBL supports the development of information literacy, which is essential in fostering critical thinking and mitigating misinformation in an increasingly digital landscape (García-Quismondo et al., 2024).

The effectiveness of PjBL in plant morphology instruction is reinforced by direct exposure to natural environments, which enhances students' ability to classify plants accurately. Learning in a real-world setting provides students with authentic experiences that strengthen their conceptual understanding and information literacy skills. Teaching materials alone may not fully convey plant morphological characteristics; thus, experiential learning is necessary (Petričević, 2022). Observing plants in their natural state improves students' concentration, engagement, and retention of information. Studies indicate that learning in natural environments facilitates better comprehension of plant classification (Astimar et al., 2019). Furthermore, hands-on experiences allow students to interact with plants directly, reinforcing their understanding through observation and experimentation (Firmansah & Suryadarma, 2019; Weri et al., 2019).

Students' information literacy skills

The assessment of students' information literacy skills following the implementation of PjBL yielded a maximum score of 3.6 and a minimum score of 1.3. with an average score of 2.5 (Table 2). The highest proportion of students (65%) demonstrated information literacy skills at the *in-progress* level, while 22% were at the *essential* level, 10% at the *proficient* level, and only 3% at the *advanced* level (Table 3).

Table 2. The average of student's information literacy skills score

Description	Information literacy score
Maximum Score	3.6
Minimum Score	1.6
Average	2.5

Table 3. Percentage of students' information literacy skills in project-based learning

Category	Number of students	Percentage
In Progress	41	65%
Essential	14	22%
Proficient	6	10%
Advanced	2	3%
Total	**63**	**100%**

Analysis of specific indicators revealed that students scored highest (mean = 2.7) in group collaboration, independent learning, responsible information usage, and knowledge seeking. The mean score for students as information seekers and quality producers was 2.3. These findings suggest that students' overall information literacy skills remained at the *in-progress* level after completing the plant morphology course using the PjBL model (Figure 2).

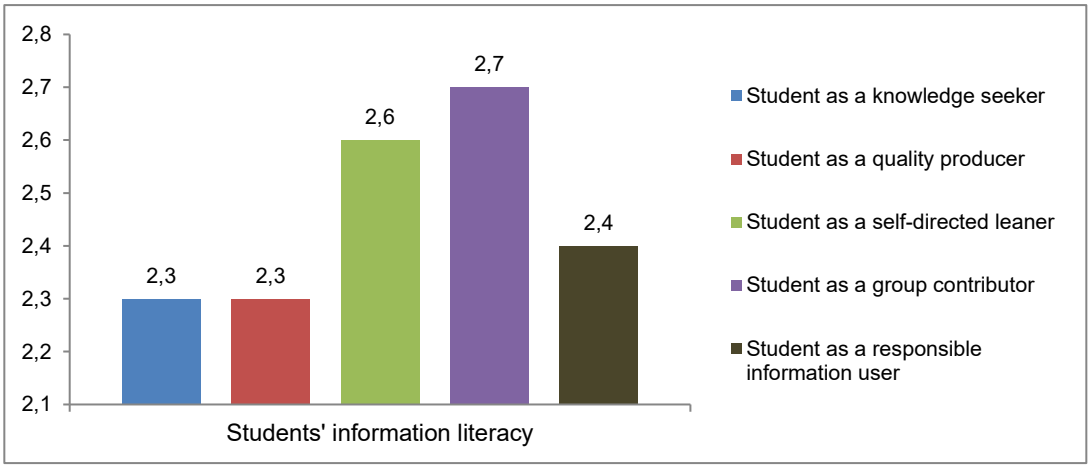

Figure 2. Diagram of students' information literacy

Further analysis of students' information-seeking abilities indicated a maximum score of 3.8, a minimum score of 1.3. and an average score of 3.0 (Table 4). The highest proficiency levels in information-seeking skills were observed among 30% of students at both the *essential* and *proficient* levels. In contrast, 24% of students were at the *in-progress* level, while 16% achieved the *advanced* level (Table 5). Within the plant morphology course, students demonstrated the strongest performance in obtaining information (mean = 3.5), followed by developing search strategies, finding relevant sources, and analyzing information (mean = 2.9). The lowest score (2.8) was recorded for the ability to determine information needs. Overall, biology education students demonstrated essential information-seeking skills (Figure 3).

Table 4. The average of students' information literacy skills as information seekers

Description	Student Score as Information Seeker
Maximum Score	3.8
Minimum Score	1.3
Average	3.0

Table 5. Percentage of students' information literacy skills as information seekers

Category	Number of students	Percentage
In Progress	15	24%
Essential	19	30%
Proficient	19	30%
Advanced	10	16%
Total	**63**	**100**

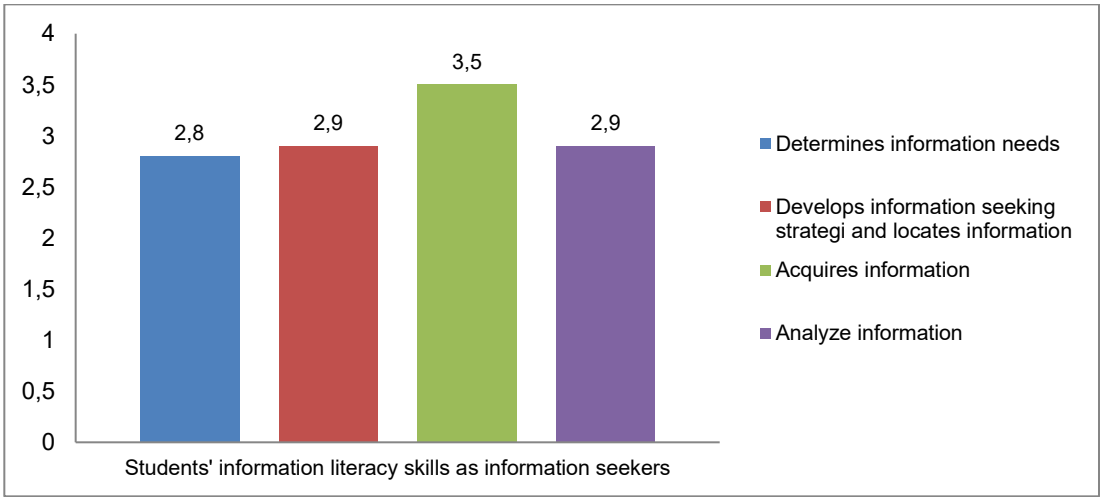

Figure 3. Diagram of students' information literacy skills as information seekers

These results indicate that information literacy development is closely linked to students' capacity to locate, evaluate, and utilize information effectively. A recent study on biology education students at Bengkulu University corroborates these findings, highlighting that 30% of students demonstrated proficiency in information literacy, 26% were in the developmental stage, and 16% reached an advanced level. The overall literacy proficiency of biology education students was categorized as *in progress* (65%). It is important to note that achieving an *advanced* level in all skill areas is not necessarily the primary objective; rather, the focus is on cultivating essential information literacy skills relevant to academic and professional settings.

The plant morphology identification project requires students to engage in an iterative knowledge acquisition process. Initially, they determine their informational needs, followed by gathering relevant data. Throughout this process, students refine their understanding by collaborating with peers, evaluating sources, and synthesizing information (Shubert, 1996). The descriptive nature of plant morphology further enhances students' ability to distinguish between plant species by focusing on morphological characteristics and scientific terminology (Arora et al., 2012; Kaplan & Specht, 2022). While students can acquire knowledge through textbooks and digital sources, direct observation in natural settings (e.g., forests, botanical gardens, experimental plots) provides deeper insights into plant morphology (Astimar et al., 2019; Valle et al., 2021). These immersive learning experiences facilitate engagement with diverse information sources, ultimately strengthening students' information literacy competencies (Tachie-Donkor & Ezema, 2023).

Several factors influence the development of information literacy skills through collaborative learning,

including: (1) Active and passive engagement with digital media; (2) Integration of student interests in task design; and (3) Collaboration through technology-supported learning (Ishimura & Fitzgibbons, 2023). This study also examines the role of instructors and students in utilizing technology and learning resources effectively (Tazieva et al., 2019). Structured collaborative assignments have been shown to promote critical discussions and informed decision-making (Davidson et al., 2019; Gaston & Havard, 2024; Mora et al., 2020). Digital learning platforms provide students with access to open virtual environments, enabling them to explore knowledge collaboratively across geographical boundaries (Baser et al., 2017; Chen, 2018).

Information literacy programs in higher education play a crucial role in equipping students with academic research skills and fostering critical engagement with information sources. Educational projects focused on information literacy emphasize critical thinking and active learning (García-Quismondo et al., 2024). University libraries serve as essential facilities for providing access to reliable academic resources, which, in turn, enhance students' competency levels in information literacy (Pinto et al., 2024; Tachie-Donkor & Ezema, 2023).

Students' information literacy skills can be further strengthened through collaborative learning experiences. Working in groups encourages peer teaching, exposure to diverse perspectives, and effective time management (Ishimura & Fitzgibbons, 2023) Innovative instructional approaches such as PjBL contribute to fostering a digitally literate and information-responsible society (García-Quismondo et al., 2024). Furthermore, positive attitudes and responsible information-seeking behavior are directly correlated with enhanced information literacy outcomes (Tachie-Donkor & Ezema, 2023). Overall, the implementation of Project-Based Learning in Plant Morphology instruction not only enhances students' information literacy skills but also deepens their understanding of plant morphological structures through direct experience in natural environments. Thus, this approach serves as an effective learning strategy for fostering critical thinking, collaboration, and student independence in accessing and managing information more effectively.

Conclusion

Project-Based Learning (PBL) in plant morphology courses has proven to be an effective instructional approach, enabling students to engage in meaningful learning experiences through the completion of mini research projects. The creation of a plant herbarium as the final product demonstrates students' ability to apply morphological identification techniques while developing essential academic competencies. The findings indicate that students' information literacy skills are at the *in-progress* level, with 65% excelling as group contributors (average score = 2.7). Additionally, their information-seeking skills are classified as *proficient*, with 30% demonstrating strong abilities in obtaining relevant information (average score = 3.5). Although the goal of achieving advanced proficiency in plant morphology identification has not been fully realized, the research highlights the importance of guiding students through the process of locating, evaluating, and applying information effectively. These findings underscore the role of PBL in fostering critical thinking, collaboration, and independent learning, which are essential for students' academic and professional development.

Acknowledgment

The authors sincerely extend their deepest gratitude to the Faculty of Teacher Training and Education at Universitas Bengkulu for their unwavering support and valuable contributions to the successful completion of this research.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

N. Murniati: methodology and writing original draft preparation; **Y. Yennita:** methodology; **D. T. O. Ha:** analysis., and **R. Riyanto:** review and editing.

References

Aghazadeh, S. (2019). *Assessment of 21 st century skills (NIE Working Paper Series No.14)* (J. Ho, B. Ng, K. H. Khng, R. De Roock, T. S. See, T. L. Yong, T. C. Lee, M. Ong, & H. Layne (eds.); Issue

14). National Institute OF Education Singapore. https://repository.nie.edu.sg/server/api/core/bitstreams/6562ac23-36db-4eae-baed-6ba00d2c9ab5/content

Aguilar, D., & Turmo, M. P. (2019). Promoting social creativity in science education with digital technology to overcome inequalities: A scoping review. *Frontiers in Psychology*, *10*(JULY). https://doi.org/10.3389/fpsyg.2019.01474/full

Akour, M., & Alenezi, M. (2022). Higher education future in the era of digital transformation. *Education Sciences*, *12*(11). https://doi.org/10.3390/educsci12110784

Arora, A., Gupta, A., Bagmar, N., Mishra, S., & Bhattacharya, A. (2012). A plant identification system using shape and morphological features on segmented lea ets: Team IITK, CLEF 2012. *CEUR Workshop Proceedings*, *1178*(1), 1–14. https://ceur-ws.org/Vol-1178/CLEF2012wn-ImageCLEF-AroraEt2012.pdf

Astimar, N., Helsa, Y., & Kenedi, A. K. (2019). The review of utilization in natural environment by the teacher as a source for learning science at elementary school in low class. *Journal of Physics: Conference Series*, *1424*(1), 1–8. https://doi.org/10.1088/1742-6596/1424/1/012036

Baser, D., Ozden, M. Y., & Karaarslan, H. (2017). Collaborative project-based learning: an integrative science and technological education project. *Research in Science and Technological Education*, *35*(2), 131–148. https://doi.org/10.1080/02635143.2016.1274723

Bielik, T., Finnie, K., Peek-Brown, D., Klager, C., Touitou, I., Schneider, B., & Krajcik, J. (2022). High school teachers' perspectives on shifting towards teaching NGSS-aligned project based learning curricular units. *Journal of Science Teacher Education*, *33*(4), 413–434. https://doi.org/10.1080/1046560X.2021.1961973

Care, E., & Kim, H. (2018). *Assessment of twenty-first century skills: The issue of authenticity*. 21–39. https://doi.org/10.1007/978-3-319-65368-6_2

Chen, C. W. yu. (2018). "Think before you type": the effectiveness of implementing an anti-cyberbullying project in an EFL classroom. *Pedagogies*, *13*(1), 1–18. https://doi.org/10.1080/1554480X.2017.1363046

Chu, S. K. W., Tse, S. K., & Chow, K. (2011). Using collaborative teaching and inquiry project-based learning to help primary school students develop information literacy and information skills. *Library and Information Science Research*, *33*(2), 132–143. https://doi.org/10.1016/j.lisr.2010.07.017

Davidson, M. A., Dewey, C. M., & Fleming, A. E. (2019). Teaching communication in a statistical collaboration course: A feasible, project-based, multimodal curriculum. *American Statistician*, *73*(1), 61–69. https://doi.org/10.1080/00031305.2018.1448890

Firmansah, & Suryadarma, I. G. P. (2019). The influence of outdoor learning model in biology instruction on the environmental care attitude of the senior high school student. *Journal of Physics: Conference Series*, *1233*(1), 1–6. https://doi.org/10.1088/1742-6596/1233/1/012012

García-Quismondo, M. Á. M., Parra-Valero, P., & Martínez-Cardama, S. (2024). A look at critical information literacy from europe's educability project. *Journal of Academic Librarianship*, *50*(5), 1–9. https://doi.org/10.1016/j.acalib.2024.102917

Gaston, J. P., & Havard, B. (2024). Collaborative video production and middle school student collaboration, engagement, and interest. *Journal of Research on Technology in Education*, 1–19. https://doi.org/10.1080/15391523.2024.2327392

GLEF. (2024). *Transforming Education - George Lucas Educational Foundation*. https://glef.org/

Griffin, P., McGaw, B., & Care, E. (2012). *Assessment and TEACHING OF 21ST CENTURY Skills*. Springer Dordrecht. https://doi.org/10.1007/978-94-007-2324-5

Hackman, T. (2012). Information pathways: A problem-solving approach to information literacy. *Library Quarterly*, *82.* 96–99. https://doi.org/10.1086/662948

Holmes, V. L., & Hwang, Y. (2016). Exploring the effects of project-based learning in secondary mathematics education. *Journal of Educational Research*, *109*(5), 449–463. https://doi.org/10.1080/00220671.2014.979911

Isabekov, A., & Sadyrova, G. (2018). Project-based learning to develop creative abilities in students. In J. Drummer, G. Hakimov, M. Joldoshov, T. Köhler, & S. Udartseva (Eds.), *Vocational Teacher Education in Central Asia. Technical and Vocational Education and Training: Issues, Concerns and Prospects* (pp. 43–49). Springer, Cham. https://doi.org/10.1007/978-3-319-73093-6_4

Ishimura, Y., & Fitzgibbons, M. (2023). How does web-based collaborative learning impact information literacy development? *The Journal of Academic Librarianship*, *49*(1). https://doi.org/10.1016/j.acalib.2022.102614

Kaplan, D. R., & Specht, C. D. (2022). *Kaplan's Principles of Plant Morphology*. CRS Press. https://doi.org/10.1201/9781315118642

Karimi, Z., Ashrafi-Rizi, H., Papi, A., Shahrzadi, L., & Hassanzadeh, A. (2015). Effect of information literacy training course on information literacy skills of undergraduate students of Isfahan University of Medical Sciences based on ACRL standards. *Journal of Education and Health Promotion*, *4*, 76. https://doi.org/10.4103/2277-9531.171789

Kartini, F. S., Widodo, A., Winarno, N., & Astuti, L. (2021). Promoting student's problem-solving skills through STEM project-based learning in earth layer and disasters Topic. *Journal of Science Learning*, *4*(3), 257–266. https://doi.org/10.17509/jsl.v4i3.27555

Kim, H. S., Ahn, S. H., & Kim, C. M. (2019). A new ICT literacy test for elementary and middle school students in Republic of Korea. *Asia-Pacific Education Researcher*, *28*(3), 203–212. https://doi.org/10.1007/S40299-018-0428-8

Klucevsek, K. M., & Brungard, A. B. (2016). Information literacy in science writing: How students find, identify, and use scientific literature. *International Journal of Science Education*, *38*(17), 2573–2595. https://doi.org/10.1080/09500693.2016.1253120

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Li, B., Jia, X., Chi, Y., Liu, X., & Jia, B. (2020). Project-based learning in a collaborative group can enhance student skill and ability in the biochemical laboratory: a case study. *Journal of Biological Education*, *54*(4), 404–418. https://doi.org/10.1080/00219266.2019.1600570

Martín Erro, A., Nuere Menéndez-Pidal, S., Díaz-Obregón Cruzado, R., & Acitores Suz, A. (2022). A framework for visual literacy competences in engineering education. *Journal of Visual Literacy*, *41*(2), 132–152. https://doi.org/10.1080/1051144X.2022.2053820

Marty, P. F., Alemanne, N. D., Mendenhall, A., Maurya, M., Southerland, S. A., Sampson, V., Douglas, I., Kazmer, M. M., Clark, A., & Schellinger, J. (2013). Scientific inquiry, digital literacy, and mobile computing in informal learning environments. *Learning, Media and Technology*, *38*(4), 407–428. https://doi.org/10.1080/17439884.2013.783596

Melinda, V., & Zainil, M. (2023). Penerapan model project based learning dalam meningkatkan komunikasi matematis siswa sekolah dasar. *Jurnal Pendidikan Tambusai*, *4*(2), 1526–1539. https://doi.org/10.36989/didaktik.v8i2.579

Mora, H., Signes-Pont, M. T., Fuster-Guilló, A., & Pertegal-Felices, M. L. (2020). A collaborative working model for enhancing the learning process of science & engineering students. *Computers in Human Behavior*, *103*. 140–150. https://doi.org/10.1016/j.chb.2019.09.008

Muhdhar, M. H. I. Al, Faruq, M. K., Sari, M. S., Sumberartha, I. W., & Mardiyanti, L. (2021). The effectiveness of the project-based learning-based ethnobotany module of Karang Kitri towards critical thinking skills. *AIP Conference Proceedings*, *2330*. https://doi.org/10.1063/5.0043107

Petričević, E. (2022). The contextual and individual determinants of engagement in learning physics. *Psihologijske Teme*, *31*(2), 383–402. https://doi.org/10.31820/pt.31.2.9

Pinto, M., Garcia-marco, J., Manso, R., Uribe, A., Caballero, D., & Gomez, C. (2024). Assessing information , media and data literacy in academic libraries : Approaches and challenges in the research literature on the topic. *The Journal of Academic Librarianship*, *50*(102920), 1–17. https://doi.org/10.1016/j.acalib.2024.102920

Raycheva, R. P., Angelova, D. I., & Vodenova, P. M. (2017). Project-based learning in engineering design in Bulgaria: expectations, experiments and results. *European Journal of Engineering Education*, *42*(6), 944–961. https://doi.org/10.1080/03043797.2016.1235140

Ruiz-Rosa, I., Gutiérrez-Taño, D., & García-Rodríguez, F. J. (2021). Project-Based Learning as a tool to foster entrepreneurial competences (El Aprendizaje Basado en Proyectos como herramienta para potenciar la competencia emprendedora). *Cultura y Educacion*, *33*(2), 316–344. https://doi.org/10.1080/11356405.2021.1904657

Saenab, S., Zubaidah, S., & Mahanal, S. (2022). Keterampilan literasi informasi dan keterampilan komunikasi mahasiswa biologi Universitas Negeri Makassar. *Jurnal Nalar Pendidikan*, *10*(1), 32–40. https://doi.org/10.26858/jnp.v10i1.

Saleh, A. R., Sujana, J. G., Ratnaningsih, & Elvina, I. (2017). *Literasi Informasi untuk Mahasiswa IPB* (Issue January). Institut Pertanian Bogor, Perpustakaan. https://www.researchgate.net/publication/316487832_Literasi_informasi_untuk_mahasiswa_IPB

Sasson, I., Yehuda, I., & Malkinson, N. (2018). Fostering the skills of critical thinking and question-posing in a project-based learning environment. *Thinking Skills and Creativity*, *29*, 203–212. https://doi.org/10.1016/J.TSC.2018.08.001

Schiffl, I. (2020). How information literate are junior and senior class biology students? *Research in Science Education*, *50*(2), 773–789. https://doi.org/10.1007/s11165-018-9710-2

Shao, X., & Purpur, G. (2016). Effects of information literacy skills on student writing and course performance. *Journal of Academic Librarianship*, *42*(6), 670–678. https://doi.org/10.1016/j.acalib.2016.08.006

Shopova, T. (2014). Digital literacy of students and its improvement at the university. *Journal on Efficiency and Responsibility in Education and Science*, *7*(2), 26–32. https://doi.org/10.7160/eriesj.2014.070201

Shubert, J. M. (1996). *Rubrics for the assessment of information literacy*. Colorado State Dept. of Education, Denver. State Library and Adult Education Office. https://files.eric.ed.gov/fulltext/ED401899.pdf

Stokes, A., & Harmer, N. (2018). The value of 'having a go': Trialing a project-based learning activity to

inform curriculum design. *Journal of Geoscience Education*, *66*(4), 278–292. https://doi.org/10.1080/10899995.2018.1509599

Tachie-Donkor, G., & Ezema, I. J. (2023). Effect of information literacy skills on university students' information seeking behaviour and lifelong learning. *Heliyon*, *9*(e18427), 1–11. https://doi.org/10.1016/j.heliyon.2023.e18427

Tazieva, V., Pavlov, Y., Todorova, K., & Katzarova, P. K. (2019). Study on the optimal usage of active and passive technology-based teaching resources. In A. L, Brooks, E. Brooks, & C. Sylla (Eds.), *nteractivity, Game Creation, Design, Learning, and Innovation* (Vol. 265, Issue 1, pp. 395–405). Springer, Cham. https://doi.org/10.1007/978-3-030-06134-0_43

Terrón-López, M. J., García-García, M. J., Velasco-Quintana, P. J., Ocampo, J., Vigil Montaño, M. R., & Gaya-López, M. C. (2017). Implementation of a project-based engineering school: increasing student motivation and relevant learning. *European Journal of Engineering Education*, *42*(6), 618–631. https://doi.org/10.1080/03043797.2016.1209462

Tong, Y., Kinshuk, & Wei, X. (2020). Teaching design and practice of a project-based blended learning model. *International Journal of Mobile and Blended Learning*, *12*(1), 33–50. https://doi.org/10.4018/IJMBL.2020010103

Valle, N., Antonenko, P., Endara, L., Davis, E. C., Somarriba, G., Sessa, E., Luo, F., Carey, S., Dogan, S., Burleigh, J. G., & Mcdaniel, S. (2021). Community science, storytelling, or inquiry-based learning? Evaluating three technology-enhanced pedagogical approaches in an online botany course. *American Biology Teacher*, *83*(8), 513–520. https://doi.org/10.1525/abt.2021.83.8.513

Weri, F., Ratnawulan, & Gusnedi. (2019). Analysis of student textbook in the development of integrated natural science student book with the theme sense of sight and optical devices using connected model for integrated 21st century learning. *Journal of Physics: Conference Series*, *1185*(1), 1--5. https://doi.org/10.1088/1742-6596/1185/1/012113

Yan, T., Wang, Z., Liao, C., Xu, W., & Wan, L. (2021). Effects of the morphological characteristics of plants on rainfall interception and kinetic energy. *Journal of Hydrology*, *592.* 125807. https://doi.org/10.1016/j.jhydrol.2020.125807