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Enhancing Scientific Literacy through Project-Based Learning in Plant Physiology: A Study of Student-Managed Cultivation Projects

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Abstract: This study addresses the persistent problem of low scientific literacy among biology education students. It aims to evaluate the effect of project-based learning (PjBL) through student-managed plant cultivation on enhancing their scientific literacy. Employing a sequential explanatory design with a mixed-methods approach, quantitative data were gathered via the Test of Scientific Literacy Skills (TOSLS), while qualitative data were collected through semi-structured interviews, documentation, and participatory observation. Quantitative analysis showed a significant increase in the mean TOSLS score from 4.43 in the pretest to 9.79 in the posttest ($p < 0.001$). Corresponding qualitative findings revealed perceived gains in critical thinking, analytical reasoning, and scientific communication, and students reported the experience as authentic and meaningful. In conclusion, PjBL proves effective in facilitating scientific literacy by integrating cognitive, social, and reflective dimensions through real-world activities such as plant cultivation, offering a robust link between theoretical knowledge and practice in science education.

Keywords: Biology education; plant physiology; project-based learning; scientific literacy; student-managed plant cultivation

Introduction

Scientific literacy in higher education is a critical competency to meet the demands of modern science and technology. In addition to knowing scientific facts, scientific literacy entails understanding scientific reasoning and procedures, empowering individuals to think critically and make informed decisions about complex scientific issues (Adhani et al., 2020; Medvecky, 2022). PISA's definition emphasizes the ability to apply scientific knowledge in real-life situations (Adhani et al., 2020; Osborne & Allchin, 2024; Rahmawati, 2020; Tang et al., 2023; Teig, 2024), showing that scientific literacy is both cognitive and social. It includes mastery of scientific knowledge, understanding scientific processes, critical thinking, and communicating and collaborating effectively (Glorifica, 2021; Münchow et al., 2019).

However, research has shown that students' scientific literacy remains suboptimal, especially in biology and plant physiology courses. It has been demonstrated that immersive botanical experiences improve students' understanding of botany and help them relate plant science to their undergraduate majors and prospective professions (Colon et al., 2020; Lindemann-Matthies et al., 2024; Supriyadi et al., 2014). Positive attitudes toward plant science and increased plant knowledge can result from educational interventions that offer meaningful and lasting hands-on experiences with plants (Krosnick & Moore, 2025; Stagg et al., 2025). Scientific literacy plays a vital role in promoting conceptual understanding and practical

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skills. Valladares (2021) argues that scientific literacy fosters social engagement and active participation in scientific dialogue. Thus, higher education must provide learning approaches that can holistically and contextually enhance scientific literacy.

Project-Based Learning (PjBL) has emerged as a promising strategy. It encourages active learning, problem-solving, and collaboration (Reswara et al., 2024; Yusof et al., 2021). Studies confirm that PjBL integrated with STEAM and socioscientific issues improves scientific literacy and motivation (Fauzi et al., 2020; Hakim et al., 2019; Kurniasari et al., 2023; Nuramalina et al., 2022). One study found that PjBL enhanced students' higher-order thinking capabilities by enhancing their metacognitive abilities and comfort with challenging real-world challenges (Affandy et al., 2024; Halmo et al., 2024; Matsuda et al., 2024). By incorporating real-world contexts and technologies, PjBL has also successfully enhanced creative thinking abilities, such as idea generation and critical thinking (Arifatin, 2023).

Despite this, not much research has specifically looked at the effects of student-run culture projects in plant physiology classes on the development of scientific literacy. Instead of examining how practical cultivation projects develop abilities like scientific communication, experimental design, and critical thinking, the majority concentrate on conceptual mastery or motivation. Thus, the following research issue is addressed in this study: To what extent does the use of student-run, project-based cultivation projects enhance scientific literacy in a course on plant physiology?

This research is distinct in its approach, integrating theoretical and practical plant physiology knowledge through real cultivation projects. It is based on social constructivist theory, which posits that learning occurs through meaningful social interaction (Hafizi, 2023; Lehtinen et al., 2023; Siregar et al., 2024), aligned with Vygotsky's zone of proximal development (Kellogg et al., 2021; Margolis, 2020; Zaretsky, 2024).

The novelty of this study is its focus on student-led culture projects, which have not been widely studied in plant physiology education as a way to bridge the gap between theoretical ideas and practical activities in plant science. This study specifically examines how hands-on cultivation improves three important areas of scientific literacy, namely reasoning, communication, and scientific practice in a lecture setting, in contrast to previous studies that emphasize subject knowledge or general motivation.

Although previous studies report the benefits of PjBL, they also point out challenges in implementation, such as resource limitations and collaboration issues (Hayashi et al., 2023; Hussein, 2021; Meng et al., 2023; Nawawi et al., 2021). Thus, this study also aims to provide strategic recommendations for managing student-led cultivation projects in ways that optimize scientific literacy outcomes.

In addition to using pedagogical strategies, this study employs validated instruments such as the TOSLS to assess cognitive and affective domains of scientific literacy (Coppi et al., 2022; Pratiwi et al., 2023; Treibergs et al., 2022).

This study is significant because it addresses a crucial need in biology education: the creation of more student-centered, contextualized, and engaging learning models that enhance understanding of the material while developing transferable scientific skills. Students are better prepared to face real-world challenges in sustainable agriculture, environmental stewardship, and scientific communication by placing learning within a practical cultivation framework. These skills are increasingly important in the 21st-century scientific landscape.

In conclusion, this study responds to the urgent need to develop context-based learning models that foster applied scientific literacy. It offers innovative insights by linking real-world cultivation practices with literacy outcomes, contributing to biology education theory and practical teaching solutions in higher education.

Method

Time and Place of Research

This study was conducted from February to June 2025 during the even semester academic schedule. Students enrolled in Plant Physiology courses in their fourth semester of the Biology Education Study Program at PGRI Silampari University participated. With 28 students, the sample balanced representativeness and practicality for comprehensive data collection. The study was conducted at PGRI Silampari University, more precisely in the Faculty of Science and Technology's Biology Education Study Program.

Tools and Materials

The research utilized a variety of tools and materials including test instruments (TOSLS) for pretest and posttest administration, interview guides for semi-structured interviews, observation sheets and field notes, student cultivation tools such as pots, planting media, seeds, and nutrient supplies, as well as documentation equipment such as cameras, voice recorders, and laptops for transcription and data management.

Research Methods

With a sequential explanatory strategy, this study uses a mixed methods design that progressively combines quantitative and qualitative methodologies. This method was selected to give a thorough picture of how independent plant cultivation projects combined with project-based learning affect students' scientific literacy and to gain a deep understanding of their experiences and viewpoints. While qualitative approaches investigate elements that facilitate and hinder learning implementation and student views, quantitative approaches quantify quantifiable gains in students' scientific literacy. Using a pretest-posttest one-group design, this study measures students' scientific literacy before and after the project-based learning intervention. This design makes it possible to gauge how much scientific literacy has improved due to the applied learning intervention.

Research Stages

Several complementing strategies were combined in the data collection process. Scientific literacy was assessed before and after the intervention using the Test of Scientific Literacy Skills (TOSLS), which was validated for use in science contexts in higher education. The test covered scientific knowledge, data analysis skills, and critical reasoning. Semi-structured interviews with a purposive sample of students were carried out, videotaped, and transcribed to gather qualitative information on their perceptions, project experiences, and factors that facilitate and hinder learning. Participatory observation was conducted by closely monitoring learning sessions, focusing on student relationships, group dynamics, and technical and non-technical challenges, particularly those related to coaching and collaborative work activities Through triangulation, documentation data, including project plans, processing reports, and student reflections, were collected to confirm findings and enhance understanding of the learning process.

Focus of Inquiry

Questions centred on various aspects of the learning experience, including the planning, execution, and assessment stages of students' project-based learning with autonomous cultivation. The inquiry explored students' views regarding the benefits of project-based learning their scientific literacy and their understanding of plant physiology. It also examined students' interest and motivation levels, including the factors that influence their engagement and participation. Challenges encountered in intellectual, social, and technical domains during the project were identified, as well as the forms of support perceived from peers, instructors, and the institution. Lastly, the study explored the extent to which project experiences impacted students' abilities in scientific analysis and communication. Open-ended inquiries enabled in-depth narrative responses and the emergence of unexpected themes.

Data Analysis

Quantitative data were analyzed using descriptive and inferential statistics. Descriptive statistics outlined the levels of scientific literacy before and after the intervention. The hypothesis that PjBL with independent cultivation projects significantly increases students' scientific literacy was tested using paired sample t-tests, which examined the statistical significance of score differences. Qualitative data from observations and interviews were analyzed thematically through transcription, repeated reading, coding, theme identification, and classification according to the study's objectives. Thematic analysis aimed to uncover students' perspectives, challenges, motivations, and forms of support during the learning process. To enhance validity, data from quantitative tests, observations, interviews, and documentation were triangulated to build a more comprehensive and accurate depiction of the studied phenomena. Finally, data interpretation and presentation involved using both quantitative and qualitative results to answer the research questions. Quantitative data provided statistical evidence of effectiveness, while qualitative findings added contextual meaning. Tables, graphs, and direct quotations from participants supported the narrative presentation.

Result and Discussion

Findings

Impact of Project-Based Learning on Students' Improvement of Scientific Literacy through Independent Plant Cultivation

Students' scientific literacy significantly improved after engaging in project-based learning with independent cultivation, according to quantitative analysis utilizing TOSLS. The mean score for all 28 respondents was 4.43 on the pretest and 9.79 on the post-test, representing a noteworthy 5.36-point increase.

Table 1. Analysis of Paired T-Tests.

Std. Deviation	t-value (paired t-test)	Degrees of Freedom (df)	p-value (2-tailed)	Conclusion
1.93	14.70	27	2.10×10^{-14}	Reject H0

A statistically significant improvement ($p < 0.05$) is indicated by the paired t-test result of 14.70 with 27 degrees of freedom and $p = 2.10 \times 10^{-14}$, confirming that the learning technique has a favourable impact on students' scientific literacy.

This conclusion is corroborated by qualitative interview data, which show gains in scientific communication, data analysis, and critical thinking abilities. According to the students, participating in the independent cultivation project gave them real-world and relevant learning opportunities that increased their understanding of plant physiology principles.

Students' Views of the Use of Project-Based Learning

A thematic analysis of 28 students' semi-structured interviews showed they had favourable opinions about the project-based learning approach. In contrast to traditional classroom instruction, students reported that this approach provided novel, engaging, and demanding experiences.

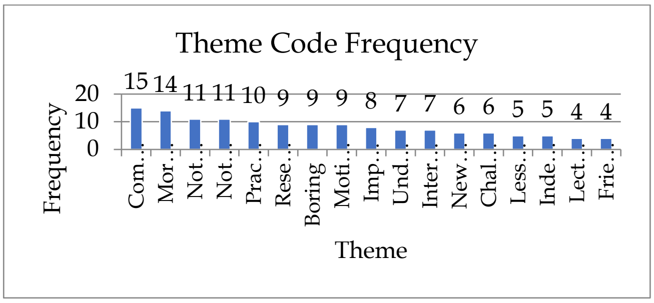

Figure 1. Diagram of Interview Themes

The primary focus was authentic learning, as students saw the physiological processes of plants in authentic settings. They valued the chance to work together, autonomously oversee projects, and develop innovative solutions to technical issues. The practical and collaborative elements that emphasized conversation and active participation particularly contributed to the notable improvement in student interest and engagement. Students expressed greater drive because they could put theory into practice and see real results. Nevertheless, obstacles included a lack of resources and equipment and issues with group member cooperation and communication. These difficulties became valuable insights for improving the learning model's efficacy and efficiency.

Factors that Encourage and Discourage the Use of Project-Based Learning

Documentation and observations revealed several enabling and impeding elements influencing the execution of the project and the development of students' scientific literacy.

Table 2. Observation Results Thematic Analysis

Observation aspect	General findings	Thematic narrative
Student involvement	High level	Active participation and ownership of the learning process
Group collaboration	Most effective	Good teamwork, some dominance issues
Problem-solving	Responsive	Identified and tackled technical issues through discussion
Use of scientific knowledge	Theory-practice integration	Applied plant physiology concepts effectively
Time management	Adequate	Initial delays but improved planning over time
Interaction with advisors	Uneven	Some groups actively consulted; others less so
Motivation and enthusiasm	High during practice	Expressed through readiness and engagement
Tool and resource usage	Careful and efficient	Tool limitations posed challenges
Technical and non-technical challenges	Weather, group dynamics	Common obstacles included bad weather and poor communication
Documentation and reporting	Variable	Some groups documented well; others less systematic

Table 3. Content Analysis of Project Documentation

Document type	Content analysis
Project plans	Most groups detailed goals, phases, and task divisions; some general
Cultivation reports	Showed active monitoring and simple analysis; well-documented groups included growth tables.
Student reflections	Expressed emotional experiences and challenges; varied critical reflection ability
Photo/video documentation	Showed real student engagement; active groups better traced the learning process.
Group meeting minutes	Quality varied from systematic notes to brief unstructured records.
Evaluation instruments	Tosls and questionnaires applied uniformly; showed improved scientific understanding
Advisor feedback	Comments showed progress and emphasized better data handling and communication.

Among the main contributing elements were input, consultation, and helpful direction from advisors during the project. A conducive learning environment was also created through effective group collaboration. Despite certain restrictions, there were sufficient supporting infrastructures, such as laboratories and cultivation grounds. Additionally, curiosity and accountability were the primary sources of students' intrinsic motivation.

Among the inhibiting factors were the lack of instruments and resources, which hampered smooth agricultural operations. Environmental factors and weather conditions were also not always favorable. Problems with group dynamics, including communication breakdowns and dominance by certain individuals, were frequently reported. Disciplined time management was necessary due to the limited project completion time. Together, these elements had an impact on learning procedures and results, and they also provided benchmarks for upcoming project-based learning enhancements.

The connection between scientific analysis and communication skills and student involvement

Improved scientific analysis and communication skills were shown to be strongly correlated with students' degrees of involvement in cultivation initiatives, according to observations and interviews. Students actively participating in the planning, execution, and assessment stages tended to be more proficient in data interpretation, experimental design, and methodical scientific reporting. Participating in group discussions, carrying out tasks responsibly, and regularly monitoring plant progress were all examples of active involvement.

Data from documentation revealed that groups engaged in active reflection and documentation exhibited improved growth in scientific literacy. Thorough cultivation reports and organized meeting minutes demonstrated improved scientific communication. On the other hand, students with little engagement found it challenging to conduct in-depth data analysis and formulate cogent scientific arguments, suggesting that practical project management experience is essential for fostering relevant scientific competencies.

Discussion

Contribution of Project-Based Learning to Enhancing Students' Scientific Knowledge

With mean scores increasing from 4.43 to 9.79 ($p < 0.001$), the quantitative analysis demonstrated a significant improvement in scientific literacy following the intervention. This bolsters the claim made by Shaffer et al. (2019) that project-based learning successfully fosters the development of fundamental scientific literacy abilities, especially in concept comprehension and the application of contextual scientific information.

According to Glorifica (2021), scientific literacy includes critical thinking, scientific reasoning, scientific knowledge mastery, and comprehension of scientific procedures. The notable rise in this study demonstrates that students gained a theoretical understanding of plant physiology and practical and critical application skills through individual plant cultivation projects. Valladares (2021) emphasizes that scientific literacy encompasses more than just factual information; it also includes analytical thinking and social engagement in scientific discourse.

Vygotsky's social constructivism theory further supports understanding this literacy improvement mechanism. PjBL's encouragement of interpersonal communication, teamwork, and group reflection aligns with the idea that knowledge is constructed via social interaction and cultural experience (Hafizi, 2023; Siregar et al., 2024). Through hands-on experience, social interactions among student groups enabled a greater knowledge and absorption of science.

This study supports the findings of Yusof et al. (2021) and Reswara et al. (2024), which demonstrate that combining PjBL with STEAM and socioscientific topics greatly improves scientific literacy and communication abilities. Furthermore, Nuramalina et al. (2022) and Hakim et al. (2019) have identified enhanced student motivation and enthusiasm during projects as critical success elements.

Students' Views of the Use of Project-Based Learning

The majority of students saw PjBL favourably, according to the thematic analysis, as a genuine and pertinent learning tool that linked plant physiology theory to practical application. According to Hidayah et al. (2024) and Cabbar & Şenel (2020), this reinforces contextual learning by emphasizing that real-world situations enhance comprehension and lessen conceptual errors.

Vygotsky's social constructivism, which holds that learning is a social construction process in group interaction, is reflected in positive perceptions of cooperation and active involvement(Suhendi et al., 2021). Fauzi et al.(2020) and Kurniasari et al. (2023) are supported by student-reported motivation and engagement, highlighting how PjBL fosters critical thinking and scientific processes through active participation. However, issues like group dynamics and resource constraints reflect Hussein's (2021) research on collaboration obstacles in PjBL, and they need to be addressed for future implementation improvements.

Students' Perceptions of Project-Based Learning Implementation

Thematic analysis showed that students positively regarded PjBL as a genuine, relevant learning medium linking plant physiology theory with real-world application. According to Hidayah et al. (2024) and Cabbar & Şenel (2020), this reinforces contextual learning by emphasizing that real-world situations enhance comprehension and lessen conceptual errors.

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Implementation Supporting and Inhibiting Factors

Essential contributing elements were found through observation and documentation, including internal motivation, group collaboration, and advisor supervision. This supports the findings of Amala et al. (2023), who emphasize the importance of lecturers in promoting the growth of scientific literacy. Social constructivism, which emphasizes social interaction in learning, aligns with effective group collaboration (Siregar et al., 2024). There is a need for improved infrastructure and project management, as evidenced by the findings of Nawawi et al. (2021) and Hussein (2021) on PjBL implementation barriers in higher education. Inhibiting issues include restricted tools, time restrictions, weather, and communication difficulties.

The connection between participation and communication and scientific analysis

Results indicate that scientific skills and student involvement level are strongly positively correlated. Since Münchow et al. (2019) stress argument evaluation in scientific literacy, active participants demonstrate superior critical thinking and scientific argumentation. This backs up the findings of Lestari & Rahmawati (2020), who discovered that PjBL combined with inquiry-based learning improves literacy and critical thinking. Yuniwati & Arshad (2024), who emphasize the importance of reflection in enhancing comprehension and motivation, also agree with active recording and reflection.

Consequences and Model Enhancement

In addition to answering research issues, the study advances scientific education theory and practice by emphasizing the development of soft skills (communication, teamwork), learning autonomy, and project adaptation. This bolsters the ideas of Ardiansyah et al. (2024) and Fauzi et al. (2020) regarding integrating science education with 21st-century skills. To assist PjBL holistically, Hujjatusnaini et al. (2022) and Park et al. (2024) recommend enhancements such as collaborative training, active lecturer facilitation, and strengthened facilities.

Conclusion

This study concludes that project-based learning through student-managed plant cultivation effectively enhances scientific literacy. Improvements in TOSLS scores and qualitative findings support gains in critical thinking, analysis, and communication. The model can be applied in similar educational contexts to bridge theory and practice. Practically, it offers a replicable strategy for promoting active, contextual science learning in higher education.

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Author Contributions

Conceptualization and methodology, R.D.J.; validation, R.D.J. and L.F.; formal analysis, investigation, resources, and data curation, writing—original draft preparation, R.D.J.; writing—review and editing, R.D.J. and L.F.; visualization, supervision, R.D.J.; project administration, L.F. and R.D.J.; funding acquisition, R.D.J. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

References

Adhani, A., Basnawati, B., Zulfadli, Z., Ariesta, C. M., Siska, M., Suhaya, S., & Ramadhan, T. P. (2020). Profil kemampuan literasi sains calon guru biologi di Universitas Borneo Tarakan. *Biopedagogia*, *2*(2), 120–129. https://doi.org/10.35334/biopedagogia.v2i2.1818

Affandy, H., Sunarno, W., Suryana, R., & Harjana. (2024). Integrating creative pedagogy into problem-based learning: The effects on higher order thinking skills in science education. *Thinking Skills and Creativity*, *53*, 101575. https://doi.org/10.1016/j.tsc.2024.101575

Amala, I. A., Sutarto, S., Putra, P. D. A., & Indrawati, I. (2023). Analysis of scientific literacy ability junior high school students in science learning on environmental pollution. *Jurnal Penelitian*

Pendidikan Ipa, *9*(3), 1001–1005. https://doi.org/10.29303/jppipa.v9i3.1816

Ardiansyah, B., Ramdani, A., Hakim, A., & Makhrus, Muh. (2024). Natural science mini project practicum through the practical instructions module for identifying natural chemicals in medicinal plants. *Ijcse*, *1*(1), 29–37. https://doi.org/10.29303/ijcse.v1i1.552

Arifatin, F. W. (2023). Project-based learning to enhance students' creative thinking skill on language learning. *Linguists : Journal of Linguistics and Language Teaching*, *9*(2), 260. https://doi.org/10.29300/ling.v9i2.3854

Cabbar, B. G., & Şenel, H. (2020). Content analysis of biology education research that used context-based approaches: the case of Turkey. *Journal of Educational Issues*, *6*(1), 203. https://doi.org/10.5296/jei.v6i1.16920

Colon, J., Tiernan, N., Oliphant, S., Shirajee, A., Flickinger, J., Liu, H., Francisco-Ortega, J., & McCartney, M. (2020). Bringing botany into focus: addressing plant blindness in undergraduates through an immersive botanical experience. *BioScience*, *70*(10), 887–900. https://doi.org/10.1093/biosci/biaa089

Coppi, M. A., Fialho, I., & Cid, M. (2022). Evidências de validade baseadas no conteúdo de um instrumento de avaliação da literacia científica. *Cadernos de Pesquisa*, 99–127. https://doi.org/10.18764/2178-2229v29n2.2022.27

Fauzi, F., Wangid, M. N., & Prasetyo, Z. K. (2020). Observational skill: the use of picture storybook with scientific approach based through project-based learning. *Proceedings of the 3rd International Conference on Learning Innovation and Quality Education (ICLIQE 2019)*. https://doi.org/10.2991/assehr.k.200129.088

Glorifica, I. (2021). Media analysis of biology teaching book grade XII: a study based on science literation category. *Indonesian Journal of Educational Research and Technology*, *1*(1), 17–22. https://doi.org/10.17509/ijert.v1i1.32659

Hafizi, Z. (2023). Evaluasi konstruktivisme sosial sebagai pendekatan pendidikan karakter di era digital. *Jurnal Ilmiah Edukatif*, *9*(2), 116–125. https://doi.org/10.37567/jie.v9i2.2519

Hakim, L., Sulatri, Y., Mudrikah, A., & Ahmatika, D. (2019). STEM project-based learning models in learning mathematics to develop 21st century skills. *Proceedings of the International Conference of Science and Technology for the Internet of Things*. https://doi.org/10.4108/eai.19-10-2018.2281357

Halmo, S. M., Yamini, K. A., & Stanton, J. D. (2024). Metacognition and self-efficacy in action: how first-year students monitor and use self-coaching to move past metacognitive discomfort during problem solving. *CBE—Life Sciences Education*, *23*(2). https://doi.org/10.1187/cbe.23-08-0158

Hayashi, V., Dutra, J., Almeida, F., Arakaki, R., Midorikawa, E., Canovas, S., Cugnasca, P., & Ruggiero, W. (2023). Implementation of PjBL with remote lab enhances the professional skills of engineering students. *IEEE Transactions on Education*, *66*(4), 369–378. https://doi.org/10.1109/TE.2023.3243532

Hidayah, M. U., Kuswanto, H., Jumadi, J., & Khotimah, K. (2024). Integration review of project based learning in biology education: a systematic literature synthesis of education levels, biology subdisciplines, research methodologies and learning competencies. *International Journal for Multidisciplinary Research*, *6*(2). https://doi.org/10.36948/ijfmr.2024.v06i02.15652

Hujjatusnaini, N., Corebima, A. D., Prawiro, S. R., & Gofur, A. (2022). The effect of blended project-based learning integrated with 21st-century skills on pre-service biology teachers' higher-order thinking skills. *Jurnal Pendidikan Ipa Indonesia*, *11*(1), 104–118. https://doi.org/10.15294/jpii.v11i1.27148

Hussein, B. (2021). Addressing collaboration challenges in project-based learning: the student's perspective. *Education Sciences*, *11*(8), 434. https://doi.org/10.3390/educsci11080434

Kellogg, D., Léopoldoff-Martin, I., & Schneuwly, B. (2021). Developing concepts of development: vygotsky's pédologie. introduction to the special issue. *Mind, Culture, and Activity*, *28*(4), 286–292. https://doi.org/10.1080/10749039.2022.2026972

Krosnick, S., & Moore, K. (2025). Rooting students in their botanical history: A method to engage students in botany and herbaria. *PLANTS, PEOPLE, PLANET*, *7*(3), 838–849. https://doi.org/10.1002/ppp3.10595

Kurniasari, R., Ridho, S., & Indriyanti, D. R. (2023). Analysis of the STEM-based blended project based learning model to improve students' science literacy. *Journal of Innovative Science Education*, *12*(1), 26–31. https://doi.org/10.15294/jise.v12i1.62296

Lehtinen, A., Kostiainen, E., & Näykki, P. (2023). Co-construction of knowledge and socioemotional interaction in pre-service teachers' video-based online collaborative learning. *Teaching and Teacher Education*, *133*, 104299. https://doi.org/10.1016/j.tate.2023.104299

Lestari, H., & Rahmawati, I. (2020). Integrated STEM through project based learning and guided inquiry on scientific literacy abilities in terms of self-efficacy levels. *Al Ibtida Jurnal Pendidikan Guru Mi*, *7*(1), 19. https://doi.org/10.24235/al.ibtida.snj.v7i1.5883

Lindemann-Matthies, P., Heber, E., & Remmele, M. (2024). Find the plant—an educational game fosters plant species literacy. *Sustainability*, *16*(11), 4702. https://doi.org/10.3390/su16114702

Margolis, A. A. (2020). Zone of proximal development, scaffolding and teaching practice. *Cultural-Historical Psychology*, *16*(3), 15–26. https://doi.org/10.17759/chp.2020160303

Matsuda, Y., Falcon, A., Porter, A., Royer, A., Mohnkern, L., Vergara, D., & Valiente, Y. (2024). Implementation of problem-based learning modules in an introduction to public health course. *Frontiers in Public Health*, *12*. https://doi.org/10.3389/fpubh.2024.1405227

Medvecky, F. (2022). Public understanding of ignorance as critical science literacy. *Sustainability*, *14*(10), 5920. https://doi.org/10.3390/su14105920

Meng, N., Dong, Y., Roehrs, D., & Luan, L. (2023). Tackle implementation challenges in project-based learning: a survey study of PBL e-learning platforms. *Educational Technology Research and Development*, *71*(3), 1179–1207. https://doi.org/10.1007/s11423-023-10202-7

Münchow, H., Richter, T., Mühlen, S. v. d., & Schmid, S. (2019). The ability to evaluate arguments in scientific texts: measurement, cognitive processes, nomological network, and relevance for academic success at the university. *British Journal of Educational Psychology*, *89*(3), 501–523. https://doi.org/10.1111/bjep.12298

Nawawi, N., Trisianawati, E., & Karim, A. (2021). Biology blog: project-based learning in pandemic periode to encourage students' creativity. *Thabiea Journal of Natural Science Teaching*, *4*(1), 111. https://doi.org/10.21043/thabiea.v4i1.8866

Nuramalina, A. R., Rahmatan, H., Safitri, R., Pada, A. U. T., Nurmaliah, C., & Evendi, E. (2022). Using project-based learning model with mind mapping method to increase students' learning motivation. *Jurnal Penelitian Pendidikan Ipa*, *8*(6), 2712–2716. https://doi.org/10.29303/jppipa.v8i6.2152

Osborne, J., & Allchin, D. (2024). Science literacy in the twenty-first century: informed trust and the competent outsider. *International Journal of Science Education*, 1–22. https://doi.org/10.1080/09500693.2024.2331980

Park, H. Y., Licon, C. V, Givens, J. E., & Sleipness, O. R. (2024). Implementation of sustainability principles in landscape architecture education: an examination of faculty attitudes and course syllabi. *International Journal of Sustainability in Higher Education*, *25*(8), 1995–2016. https://doi.org/10.1108/ijshe-02-2023-0060

Pratiwi, M. K., Kuntjoro, S., Sunarti, T., & Budiyanto, M. (2023). TOSLS cognitive instrument to measure students' scientific literacy abilities. *Ijorer International Journal of Recent Educational Research*, *4*(6), 819–826. https://doi.org/10.46245/ijorer.v4i6.432

Rahmawati, M. S. (2020). Meningkatkan Hasil Belajar Matematika Materi Pokok Bilangan pada Peserta Didik MI Negeri Karang Poh Pulosari Pemalang Melalui Strategi Think Talk Write (TTW). *Indonesian Journal of …*, *1*(2), 199–210.

Reswara, T. R., Parno, P., Nugraheni, D., Suwasono, P., Jannah, R., & Khamis, N. (2024). Analysis of student scientific literacy skills on energy and simple machines topics. *Journal of Physics Conference Series*, *2900*(1), 12022. https://doi.org/10.1088/1742-6596/2900/1/012022

Shaffer, J. F., Ferguson, J., & Denaro, K. (2019). Use of the test of scientific literacy skills reveals that fundamental literacy is an important contributor to scientific literacy. *Cbe—Life Sciences Education*, *18*(3), ar31. https://doi.org/10.1187/cbe.18-12-0238

Siregar, T. E., Luali, N., Vinalistyosari, R. C., Hanurawan , F., & Anggraini, A. E. (2024). Implementation of Vygotsky's constructivism learning theory through project-based learning (PjBL) in elementary science education. *Al Qalam Jurnal Ilmiah Keagamaan Dan Kemasyarakatan*, *18*(4), 2586. https://doi.org/10.35931/aq.v18i4.3620

Stagg, B. C., Hetherington, L., & Dillon, J. (2025). Towards a model of plant awareness in education: a literature review and framework proposal. *International Journal of Science Education*, *47*(4), 539–559. https://doi.org/10.1080/09500693.2024.2342575

Suhendi, A., Purwarno, P., & Chairani, S. (2021). Constructivism-based teaching and learning in Indonesian education. *Kne Social Sciences*, 76–89. https://doi.org/10.18502/kss.v5i4.8668

Supriyadi, Hartati, S., & Aminudin, A. (2014). Kajian Pemberian Pupuk P, Pupuk Mikro dan Pupuk Organik Terhadap Serapan P dan Hasil Kedelai (Glycine max L.) Varietas Kaba di Inseptisol Gunung Gajah Klaten. *Cakra Tani - Jurnal Ilmu-Ilmu Pertanian*, *XXIX*(2), 81–86.

Tang, X., Liu, Y., & Milner-Bolotin, M. (2023). Investigating student collaborative problem-solving competency and science achievement with multilevel modeling: Findings from PISA 2015.

PLOS ONE, *18*(12), e0295611. https://doi.org/10.1371/journal.pone.0295611
Teig, N. (2024). Uncovering student strategies for solving scientific inquiry tasks: insights from student process data in PISA. *Research in Science Education*, *54*(2), 205–224. https://doi.org/10.1007/s11165-023-10134-5
Treibergs, K. A., Esparza, D., Yamazaki, J. A., Goebel, M., & Smith, M. K. (2022). How do introductory field biology students feel? Journal reflections provide insight into student affect. *Ecology and Evolution*, *12*(11). https://doi.org/10.1002/ece3.9454
Valladares, L. (2021). Scientific literacy and social transformation. *Science & Education*, *30*(3), 557–587. https://doi.org/10.1007/s11191-021-00205-2
Yuniwati, E. D., & Arshad, Egr. I. (2024). Utilizing University Food Gardens as an instructional tool for teaching horticulture: gaining insights from project experience. *Amca Journal of Community Development*, *4*(1), 1–9. https://doi.org/10.51773/ajcd.v4i1.317
Yusof, W. R. W., Kimi, M., Zullkiplee, W. S. H. W., Zailani, M. A., Shahabudin, M., Ismail, A. A., Aziz, S. M. A., Ismail, I. N. A., & Gopal, D. J. R. (2021). Assessment of practical and scientific writing skills for pre-university students through project-based learning. *Journal of Chemical Education*, *99*(2), 715–722. https://doi.org/10.1021/acs.jchemed.1c00843
Zaretsky, V. K. (2024). Zone of proximal development: evolution of the concept. *Cultural-Historical Psychology*, *20*(3), 45–57. https://doi.org/10.17759/chp.2024200305