Jurnal Biolokus: Jurnal Penelitian Pendidikan Biologi dan Biologi
Vol. 9, Issue 1, June 2026
Pages : 182 – 193

p-ISSN: 2621-3702
e-ISSN: 2621-7538

The effect of lesson study-integrated problem-based learning on students' critical thinking in environmental change

Wawan Pat Atmojo[1], Natalia Rosa Keliat[1*], Sucahyo[2]
[1]Department of Biology Education, Faculty of Biology, Universitas Kristen Satya Wacana, Jl. Diponegoro No. 52/60, Sidorejo Lor, Sidorejo, Salatiga, Central Java, 50711, Indonesia.
[2]Department of Biology, Faculty of Biology, Universitas Kristen Satya Wacana, Jl. Diponegoro No. 52/60, Sidorejo Lor, Sidorejo, Salatiga, Central Java, 50711, Indonesia.
*corresponding author: natalia.keliat@uksw.edu

ABSTRACT

Although Problem-Based Learning (PBL) has been widely recognized for improving students' critical thinking skills, studies examining how Lesson Study (LS) strengthens the implementation of PBL, particularly in environmental change learning, remain limited. Therefore, this study aimed to identify the good practices of Lesson Study implementation and examine the effect of integrating Lesson Study into PBL on students' critical thinking skills. A mixed-methods approach was employed, combining qualitative and quantitative methods. Qualitative data were analyzed to identify the good practices of Lesson Study implementation, while quantitative data were collected using a quasi-experimental pretest–posttest control group design. The study involved two equivalent classes selected through a placement test, comprising 30 students in the experimental (PBL-LS) group and 30 students in the control (PBL) group. Lesson Study was implemented through four cycles consisting of the plan, do, and see stages. Quantitative data were analyzed using the Wilcoxon Signed-Rank Test and Mann–Whitney U Test. The results showed that Lesson Study generated good practices through improved lesson planning, more responsive instruction, and continuous reflection-based improvement. The PBL-LS model significantly improved students' critical thinking skills ($p < 0.05$), achieved a higher N-Gain score (0.63) than the PBL group, and showed significantly better critical thinking performance. These findings suggest that integrating Lesson Study into PBL strengthens instructional effectiveness and provides biology teachers with an effective approach to enhancing students' critical thinking skills in environmental change learning.

Keywords: Critical thinking skills, environmental change, lesson study, problem based learning

INTRODUCTON

Environmental change refers to transformation that occurs when the quality or balance of nature is disrupted, either due to natural factors or human activities. Such change may be caused by activities such as pollution, excessive deforestation, or overexploitation of natural resources (Haris et al., 2023). This problem can have fatal consequences for living organisms and their surrounding environments. Environmental change can lead to climate change, which has currently become a highly crucial global issue; conversely, climate change can also trigger environmental change.

Indonesia ranks fourth among the world's most populous countries and has experienced an increase in waste production (Wikurendra et al., 2024). According to data from the National Waste Management Information System (SIPSN) in 2023 the largest proportion of waste in Indonesia comes from food waste. Accumulated food waste can produce greenhouse gases such as methane and CO_2, which are released into the atmosphere and contribute to climate change (Handoyo & Asri, 2023). Other contributing factors include land-use conversion excessive use of motor vehicles producing emissions, and excessive electricity consumption (Nufutomo, 2022).

These environmental changes have led to various impacts, such as rising global temperatures, altered rainfall patterns, biodiversity loss, flooding, landslides, and increased risks of disease transmissions

(Nufutomo, 2022). Therefore, developing students' understanding of environmental change and their ability to address related problems has become an important objective of science education.

These phenomena of environmental change require serious handling and attention from multiple stakeholders. In the field of education, the senior high school curriculum includes environmental change as one of the topics in biology learning. To support this, classroom learning must be well prepared so that students develop broad insight and sensitivity toward global issues and climate change. UNICEF (2021) emphasizes that integrating climate change issues into educational curricula is one of strategies to address existing problems (Dira et al., 2024).

In the senior high school science curriculum, climate change material is positioned in Phase E, with learning outcomes expecting students to apply scientific understanding to address problems related to climate change. Addressing issues related to climate change and selecting solutions to environmental problems requires critical thinking skills. Critical thinking skills are competencies possessed by students to make careful judgments, decisions, and solve problems in daily life (Zubaidah et al., 2018). According to Ennis (1996), critical thinking consists of six components: (1) focus—ability to concentrate on statements or issues to make decisions; (2) reason—ability to generate reasons supporting or rejecting decisions based on facts; (3) inference—ability to draw accurate conclusions; (4) situation—ability to understand and maintain situational context in thinking; (5) clarity—ability to explain the terms used; and (6) overview—ability to review and re-examine decisions made.

However, several instructional practices still do not align with the expected learning objectives and outcomes. Najaah & Amrulloh (2022) and Febrianti (2023) explain that teachers still predominantly use lecture-based methods in teaching environmental change or global warming topics. Teacher-centered instruction in environmental change materials tends to make students passive, with learning occurring in a one-way manner (Nisak & Susanti, 2023).

Based on these conditions, constructive and student-centered learning is required so that students can understand the material well by constructing their own understanding (Lestari et al., 2017). Lesson Study (LS) is a professional development approach that focuses on teaching practices and high-quality student learning, implemented collaboratively and continuously. Teacher collaboration in solving instructional problems, evaluating classroom learning, and formulating learning objectives is one of the strengths of LS, resulting in high-quality instruction (Budiningsih, 2022; Sapitri et al, 2024). The goal of LS is to improve student learning outcomes, with teachers acting as facilitators who collaborate with other teachers in designing learning activities to achieve objectives and support students in developing knowledge (Ghofar & Wicaksono, 2020).

The implementation of LS includes three stages: plan, do, and see. In the plan stage, teachers collaborate with the LS team to select materials and learning outcomes, formulate learning objectives, prepare teaching modules, lesson designs, lesson chapters, and student worksheets. During this stage, the LS team provides feedback to the model teacher regarding the learning process to be implemented in the do stage. In the do stage, the learning process is carried out according to the plan. Other teachers act as observers, monitoring learning activities using observation sheets, observing student learning activities and the model teacher's instructional practices.

The see stage involves reflection and evaluation of the learning process implemented in the do stage (Hadianta et al., 2024). Led by a moderator, the reflection begins with the model teacher and is followed by observers. This stage aims to improve learning for subsequent meetings. Through this collaborative reflection process, teachers can evaluate instructional practices, exchange knowledge, and develop professional competence to improve learning quality (Keliat et al., 2025) . All observed student learning activities are reported, and observers also convey best teaching practices that can be applied in environmental change instruction.

Teacher collaboration in LS is essential throughout planning, implementation, and reflection stages, as many teachers still experience difficulty in designing learning plans that enhance critical thinking skills. Collaboration enables teachers to receive input and assistance from peers. Collaboration during implementation is also needed to observe and record learning activities, note learning difficulties, and identify best practices. During the see stage, collaboration facilitates evaluation of student learning experiences, identification of effective practices, and determination of instructional improvements, leading to successful learning outcomes (Auliah & Cahyani, 2025).

LS implementation can be integrated with Problem-Based Learning (PBL). The PBL process begins with orientation to a problem, followed by organizing students for learning, guiding individual or group investigation, presenting work results, and finally analyzing and evaluating the problem-solving process (Arends, 2008). According to Satwika et al. (2018), implementation of PBL can enhance students' critical thinking skills by training them to find solutions to problems. Presenting contextual problems such as environmental change issues in classroom learning can improve students' argumentation skills in solving problems (Apriyani & Alberida, 2023).

Previous studies have consistently demonstrated that Problem-Based Learning (PBL) effectively promotes students' critical thinking skills through authentic problem-solving activities and environmental learning contexts (Cong & Ironsi, 2025). Likewise, Lesson Study (LS) has been widely recognized as an effective collaborative professional development approach that enhances instructional quality through collaborative lesson planning, classroom observation, and reflective practice (Kager et al., 2024). Furthermore, integrating Lesson Study into Problem-Based Learning has been reported to improve students' collaborative skills by strengthening teacher collaboration, lesson planning, and classroom implementation (Keliat et al., 2025). Although both approaches have shown positive contributions to teaching and learning, previous studies have generally examined PBL and Lesson Study independently. Consequently, little is known about how Lesson Study can strengthen the implementation of PBL to improve students' critical thinking skills, particularly in environmental change learning. Theoretically, integrating Lesson Study into PBL is expected to enhance the quality of problem-based instruction by enabling teachers to continuously refine lesson planning, classroom facilitation, and instructional strategies through collaborative reflection. Such improvements may provide richer learning experiences that better support students' critical thinking than the implementation of PBL alone.

The novelty of this study lies in integrating Lesson Study as a collaborative professional development approach with Problem-Based Learning as a student-centered instructional model in environmental change learning. This integration is expected to improve the quality of learning implementation while simultaneously fostering students' critical thinking skills. Based on this rationale, this study aims to determine: (1) best practices of the LS approach in environmental change learning; and (2) influence of PBL model with LS approach on critical thinking skills in environmental change material.

METHOD

The study was conducted from February to May 2025 at SMA Negeri 2 Salatiga during the second semester of the 2024/2025 academic year. This study employed a quasi-experimental pretest–posttest control group design, complemented by qualitative descriptive analysis of Lesson Study (LS) implementation. The quantitative component examined the effect of Problem-Based Learning (PBL) integrated with Lesson Study (LS) on students' critical thinking skills using a pretest–posttest control group design. The qualitative component was conducted to identify the best practices of Lesson Study implementation in environmental change learning through data reduction, data display, and conclusion drawing. The following is the quantitative research design carried out (Table 1).

Table 1. Research design scheme

Group	Pretest	Treatment	Posttest
Exprimental group	O_1	X	O_2
Control grop	O_3	-	O_4

The population consisted of Grade X students at SMA Negeri 2 Salatiga. Five Grade X classes completed a placement test consisting of 10 essay questions measuring students' critical thinking skills on environmental change. Students' responses were scored using the critical thinking scoring rubric based on (Ennis, 1996) indicators. The placement test scores were analyzed using one-way ANOVA followed by Tukey's HSD post hoc test to identify homogeneous groups. Based on the post hoc analysis, two classes (XA and XE) with no significant difference in their initial abilities ($p > 0.05$) were purposively selected as the research subjects. The experimental group (XA) and the control group (XE) each consisted of 32 students aged approximately 15–16 years. Both groups comprised 14 male and 16 female students. Six biology/science teachers participated in the Lesson Study activities.

Data analysis to determine the influence of PBL model with LS approach on environmental change material on critical thinking skills using inferential statistics with several stages, namely: (1) analysis prerequisite tests which include normality and homogeneity tests to ensure that data is normally distributed and has the same variation, and (2) hypothesis testing using Wilcoxon test to see the difference in critical thinking skills test results before and after treatment. The Wilcoxon test was chosen because the results of the normality test showed that the data was not normally distributed. In addition, the N-Gain calculation was used to determine the extent of the increase in critical thinking skills in each group by Hake (1999).

Descriptive data analysis was conducted to illustrate trends in learning outcomes through average scores and N-gain categories. The quantitative instrument consisted of 10 essay questions on environmental change developed based on Ennis (1996) critical thinking framework. The test blueprint covered six critical thinking indicators: focus, reason, inference, situation, clarity, and overview. Each item was mapped to one or more critical thinking indicators and was assessed using an analytic scoring rubric with a score range of 1–5, where higher scores indicated better performance in conceptual understanding, reasoning, use of evidence, and drawing conclusions. The scoring rubric used to assess students' critical thinking skills is presented in Table 2.

Table 2. Scoring rubric critical thinking skills.

Score/ point	Descriptor
5	• All concepts are presented accurately, clearly, and precisely. • All explanations provided are accurate, clear, and specific, supported by strong and appropriate reasoning and well-developed arguments. • The reasoning demonstrates a good level of thinking, with all concepts logically interconnected and well integrated. • Grammar is used accurately and appropriately throughout.

Score/ point	Descriptor
	• All relevant aspects are clearly demonstrated, with evidence that is appropriate, sufficient, and well balanced.
4	• Demonstrates a generally accurate and clear understanding of most concepts, although some concepts are not explained in sufficient detail or specificity. • Provides mostly accurate and clear explanations, but some responses lack adequate specificity and depth. • Demonstrates good reasoning skills, with most concepts logically related to one another and appropriately integrated. • Uses generally correct and appropriate grammar, with only a few minor grammatical errors. • Addresses all relevant aspects of the task; however, the supporting evidence and discussion are not fully balanced across all aspects.
3	• Demonstrates a limited understanding of the concepts, with only a small number of concepts presented accurately and clearly. • Provides a limited number of correct and clear explanations; however, the supporting arguments are not sufficiently clear or well developed. • Demonstrates a satisfactory level of reasoning, although only a few concepts are logically connected to one another. • Uses generally acceptable grammar, but several spelling and language errors are present. • Most of the concepts presented are identifiable and generally accurate, although some may require further clarification or improvement.
2	• Demonstrates a limited and unfocused understanding of the concepts, with some ideas appearing exaggerated, uncertain, or insufficiently supported. • Provides explanations that are inadequate and do not sufficiently support the answers or conclusions presented. • Demonstrates weak reasoning, with concepts presented independently and lacking clear logical connections or relationships. • Uses generally acceptable grammar; however, several sentences are incomplete and affect the clarity of the response. • Only a small portion of the concepts presented are accurate or appear to be correctly understood.
1	• Demonstrates an inadequate understanding of the concepts, with the concepts presented being inaccurate, incomplete, or insufficient. • Provides incorrect reasoning that does not appropriately support the answer or conclusion. • Demonstrates weak and ineffective thinking, with limited evidence of logical reasoning or meaningful analysis. • Uses grammar inaccurately, with frequent errors that interfere with the clarity and understanding of the response. • Fails to adequately address the required aspects of the task, with insufficient evidence, explanation, and supporting information.
0	• Response is provided, or the response given is entirely incorrect and does not address the question appropriately.

(Zubaidah et al., 2018)

Table 3. Examples of critical thinking skills instruments compiled in the research.

Learning Outcomes	Question Indicators	Critical Thinking Skills	Question
Students will have the ability to understand measurement systems, alternative energy, ecosystems, biotechnology,	Given an article with examples of environmental change, students can explain the environmental facts that are occurring.	Focus	Article 1 is presented. Based on the article, provide your opinion on the possible consequences of forest land conversion.

Learning Outcomes	Question Indicators	Critical Thinking Skills	Question
biodiversity, atomic structure, chemical reactions, the basic laws of chemistry, and climate change, enabling them to be responsive and play an active role in providing solutions to local and global issues. All of these efforts are directed toward achieving the Sustainable Development Goals (SDGs).	Given a question with the same example as question number 1, students are able to analyze the causal relationship between human activities and environmental change.	Reason	Given article 1. Why can the activity of converting forest land to plantations cause climate change? Explain the causal relationship!
	Students are asked to relate the answer to question number 4 and provide arguments related to the factors causing global temperature increase.	Inference	Provide arguments for why these factors cause temperature increase!
	Students are asked to analyze government policies related to the ban on land conversion.	Clarity	Article 3 is presented. Is the policy implemented in the article above appropriate? Analyze the policy!
	Students are asked to analyze government policies related to the ban on land conversion. Given an article, students are asked to write about the impact of greenhouse gases on the global environment.	Situation	Article 4 is presented. Analyze the impact of the greenhouse effect on the global environment!
	A conclusion is provided in the form of a government policy related to efforts to address environmental pollution. Students are asked to provide an opinion on its accuracy and draw a conclusion.	Overview	Article 5 is presented. The government has issued policies related to efforts to address environmental pollution, one of which is air pollution, as described above. In your opinion, are these policies appropriate? Provide a conclusion!

The procedures of the study are: 1) During the preliminary study, the researcher collected initial data through observations and interviews at schools regarding problems experienced by students, the learning process at the target schools, teachers' difficulties in delivering material related to environmental change, and information regarding teaching methods used by teachers, as well as the learning models and approaches used. 2) Preparation of research instruments in the form of student worksheets, teaching modules, and critical thinking skills questions. Instrument development was carried out by considering learning outcomes, learning objectives, and characteristics. 3) Instrument validation was conducted by experts to ensure the appropriateness of the content, construct, and language before use in the research. 4) Pretest data collection. 5) The implementation of lesson study which begins with a planning activity carried out to determine the date of the research implementation, compiling the teaching module, lesson design, and lesson chapter, the do stage, the see stage. After the 1st LS cycle was implemented, it was continued with the rearrangement of LS activities starting from plan, do, to see, where LS was carried out in 4 cycles; 6) Posttest data collection; 7) Data processing and analysis of results.

Empirical validity was assessed using the Pearson Product Moment correlation test based on the responses of students from Grade X class XC, which was not included as either the experimental or control group. The correlation between each item score and the total test score was analyzed using SPSS. All ten essay items showed significance values below 0.05 ($p < 0.05$), indicating that each item was empirically valid and suitable for measuring students' critical thinking skills.

Content validity was assessed by two expert validators with expertise in biology education, environmental science, and instructional design. The validators evaluated the teaching module, student worksheet, and critical thinking skills test using a five-point rating scale covering aspects of content, construct, and language. The final validity score (Va) was obtained by averaging the validators' scores. According to Hobri (2021), instruments with a validity score of $4 \leq Va \leq 5$ are categorized as valid. The critical thinking skills test obtained a validity score of 4.81, the teaching module 4.61, and the student worksheet 4.71, indicating that all instruments met the validity criteria.

Instrument reliability was assessed by two expert validators using the inter-observer reliability coefficient proposed by Emmer and Millet (Kubiszyn & Borich, 2016). The reliability coefficient was calculated based on the level of agreement between the validators' ratings for each instrument. The teaching module, student worksheet (LKPD), and critical thinking skills test achieved reliability coefficients of 92.52%, 95.33%, and 96.00%, respectively. Since all coefficients exceeded the minimum criterion of 75%, all instruments were considered reliable and suitable for use in the study.

The empirical reliability of the critical thinking skills test was assessed using the responses of students from Grade X class XC. Cronbach's Alpha analysis performed using SPSS yielded a coefficient of 0.87, indicating high internal consistency. Therefore, the instrument was considered reliable and suitable for use in the main study. Prior to hypothesis testing, the data were tested for normality. The normality test indicated that the data were not normally distributed ($p < 0.05$); therefore, non-parametric statistical tests were employed. The Wilcoxon Signed-Rank Test was used to determine differences between pretest and posttest scores within each group, whereas the Mann–Whitney U Test was used to compare critical thinking skills between the experimental (PBL-LS) and control groups. Statistical significance was set at the 0.05 level.

RESULTS AND DISCUSSION

The implementation of LS demonstrated best practices across Plan, Do, and See stages, reflected in consistent reflection and improvement patterns. During the plan stage, the model teacher received conceptual reinforcement and feedback from the LS team, including material deepening, refinement, addition of contextual examples, strengthening of PBL syntax, and anticipation of classroom management strategies. These inputs resulted in increasingly structured learning designs aligned with student characteristics. Table 4 shows the results of Plan meetings 1 – 4.

Table 4. Finding result of Plan stage

Criteria/ Indicator	Improvements at each planning stage (meetings 1–4)
Content Deepening	Learning content was refined through the addition of contextual environmental issues (e.g., acid rain), reinforcement of key concepts, and adjustment of material focus based on observer feedback.
Student Worksheets	Worksheets were continuously revised to improve learning flow, contextual problem cases, presentation activities, and investigation tasks based on reflection results.
Learning model	The PBL-LS syntax was refined to strengthen problem orientation, investigation, discussion, and presentation activities, supported by improved questioning strategies.
Classroom manage-ment	Planning focused on group organization, time allocation, monitoring of mobile phone use, and strategies to improve student engagement and classroom control.

The Plan stage demonstrated continuous improvement in lesson preparation across the four LS cycles. Observer feedback focused on content deepening, refinement of student worksheets, strengthening of PBL syntax, and classroom management strategies. These improvements resulted in more structured learning activities that were better aligned with student needs (Table 5).

Table 5. Finding results of Do stage

Criteria/ Indicator	Findings and improvements at the Do stage (meetings 1–4)
Content deepening	Students demonstrated improved understanding of environmental change concepts through discussions, investigations, presentations, and teacher reinforcement.
Student worksheets	The use of worksheets became more effective as teachers provided clearer instructions and guidance. Students showed better performance in completing worksheet phases, analyzing data, and producing more accurate and organized work.
Teaching module	Implementation of the PBL-LS syntax became increasingly consistent, with improved facilitation of problem orientation, investigation, presentation, and concept reinforcement activities.
Classroom manage-ment	Classroom management improved through better lesson preparation, time management, monitoring of mobile phone use, student participation, and teacher feedback. Learning disruptions decreased, student focus increased, and group collaboration became more effective across meetings.

The Do stage revealed progressive improvements in instructional implementation. Students became more actively engaged in discussions, investigations, and presentations, while teachers showed greater proficiency in facilitating PBL activities and managing classroom dynamics. Observer reports also indicated improvements in the use of worksheets, concept reinforcement, student participation, and time management across successive meetings (Table 5).

The See stage generated collaborative reflections that focused on student learning processes rather than teacher performance. Reflections highlighted areas for improvement, including concept reinforcement, time management, classroom focus, and device use. At the same time, observers noted positive developments such as improved student readiness, increased creativity in learning products, stronger classroom management, and more effective teacher responses to student learning difficulties. These findings informed subsequent lesson improvements and contributed to the continuous refinement of instructional practices

The Wilcoxon Signed-Rank Test was conducted to examine the effect of Problem-Based Learning integrated with Lesson Study (PBL-LS) on students' critical thinking skills because the data were not normally distributed. The results showed a statistically significant improvement in students' critical thinking skills after the implementation of PBL-LS ($Z = -4.795$, $p < 0.001$). The calculated effect size was large ($r = 0.88$), indicating that the intervention had a strong positive effect on students' critical thinking skills.

The N-Gain analysis further supported the effectiveness of PBL-LS. The experimental class achieved an N-Gain score of 0.63, which was higher than that of the PBL class (0.47), indicating greater improvement in students' critical thinking skills. This finding is consistent with the Wilcoxon test, which demonstrated a statistically significant improvement with a large effect size ($r = 0.88$). Together, these findings suggest that integrating Lesson Study into Problem-Based Learning contributed to greater improvements in students' critical thinking skills than the implementation of PBL alone. The results are presented in Table 6.

Table 6. N-gain test of critical thinking skills of PBL-LS and PBL classes.

Class	N-Gain	Description
PBL-LS	0.63	Medium
PBL	0.47	Medium

N-Gain analysis further supported the effectiveness of PBL-LS. As shown in Table 6, the PBL-LS class achieved a higher N-Gain score (0.63) than the PBL class (0.47), although both were categorized as moderate. This finding suggests that integrating Lesson Study into PBL contributed to greater improvements in students' critical thinking skills.

Furthermore, the Mann–Whitney U test was conducted to compare students' critical thinking skills between the experimental (PBL-LS) and control (PBL) groups because the data were not normally distributed. The results revealed a significant difference between the two groups ($U = 150.50$, $Z = -4.441$, $p < 0.001$), with a large effect size ($r = 0.57$). The experimental group also obtained a higher mean posttest score (72.33) than the control group (62.46), as illustrated in Figure 1. These findings indicate that integrating Lesson Study into PBL was associated with greater improvements in students' critical thinking skills than implementing PBL alone, which can be seen in Figure 1.

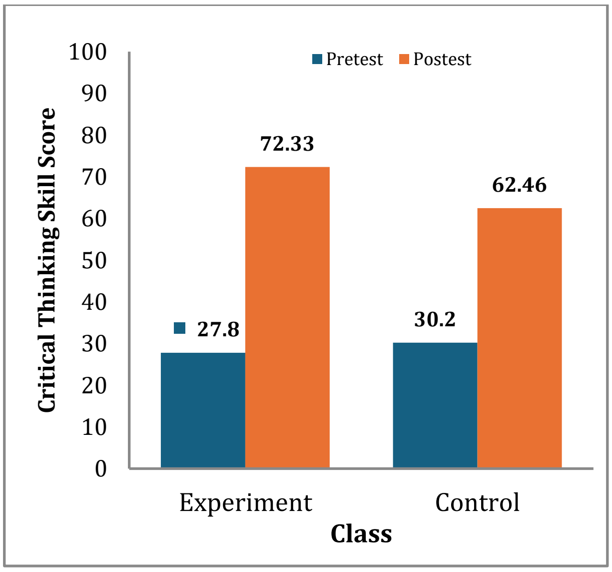

Figure 1. Graph of average critical thinking skills scores

The significantly higher critical thinking scores achieved by the PBL-LS class suggest that Lesson Study enhanced the effectiveness of Problem-Based Learning This finding is consistent with previous studies showing that PBL can improve critical thinking skills by engaging students in active investigation, problem analysis, and solution development during biology learning (Ramadhan & Mardin, 2023) . While PBL engages students in analyzing authentic environmental problems and developing solutions, Lesson Study continuously improves the quality of its implementation through collaborative planning, observation, and reflection. Through the plan, do, and see cycles, teachers refined learning materials, strengthened questioning strategies, improved classroom management, and adjusted instructional approaches based on students' learning needs. These improvements created a more supportive learning environment for developing critical thinking skills (Ratnaningsih et al., 2022).

Yildiz and Baltaci (2017) reported that Lesson Study contributes to teachers' pedagogical improvement through systematic reflection and collaboration. More recently, Yu and Zin (2023) explained that Problem-Based Learning promotes students' critical thinking by engaging learners in authentic problem solving, collaborative inquiry, and reflective learning activities. Similarly, Loyens et al. (2023) emphasized that student-centered problem-based learning environments foster higher-order thinking through active collaboration and meaningful learning experiences. The present study extends these findings by demonstrating that integrating Lesson Study into PBL not only improved instructional practices but also resulted in greater gains in students' critical thinking skills.

Pedagogically, collaborative lesson planning enabled teachers to refine contextual learning materials, improve student worksheets, and anticipate students' learning difficulties before instruction. This process reflects the role of Lesson Study in developing teachers' pedagogical competence through collaborative planning, classroom observation, and reflective evaluation (Wulandari et al., 2023).

Furthermore, classroom observation and reflective discussion after each lesson provided evidence-based feedback that allowed teachers to continuously improve questioning strategies, classroom facilitation, and classroom management. These continuous improvements were reflected across the four Lesson Study cycles, resulting in more effective classroom interactions and greater student engagement during problem-solving activities. Consequently, students experienced richer classroom discussions and repeated opportunities to analyze environmental issues, evaluate evidence, justify their reasoning, and construct knowledge actively. These findings support constructivist learning theory, which emphasizes that knowledge is actively constructed through problem solving, social interaction, and reflection.

CONCLUSION

Based on the findings, the implementation of Lesson Study in environmental change learning generated good practices across the plan, do, and see stages, leading to continuous improvements in instructional quality. The integration of Lesson Study into Problem-Based Learning enhanced students' critical thinking skills and demonstrated greater learning effectiveness than the implementation of Problem-Based Learning alone. The main contribution of this study lies in demonstrating that Lesson Study not only serves as a collaborative professional development approach for teachers but also strengthens the implementation of Problem-Based Learning through continuous planning, observation, and reflection, thereby creating more meaningful learning experiences that support students' critical thinking. Practically, PBL-LS may serve as an effective instructional approach for biology teachers to promote students' critical thinking skills, particularly in environmental change learning. Future research is recommended to examine the implementation of PBL-LS across other biology topics, educational levels, and larger samples to further investigate its impact on students' higher-order thinking skills.

REFERENCES

Apriyani, N. D., & Alberida, H. (2023). Pengaruh model Problem Base Learning (PBL) terhadap keterampilan argumentasi peserta didik pada pembelajaran biologi: Literature review. *BIOCHEPHY: Journal Of Science Education*, *03*(1), 40–48.

Arends, R. I. (2008). *Learning to teach* (9th ed.). McGraw-Hill.

Auliah, A., & Cahyani, V. P. (2025). Integrasi lesson study dalam model pembelajaran kolaboratif untuk meningkatkan kualitas pembelajaran. *MACCA: Science-Edu Journal*, *2*(1), 285–295. https://doi.org/10.51574/msej.v2i1.2834

Budiningsih, D. N. (2022). Penerapan lesson study berbasis problem-based learning untuk meningkatkan keaktifan belajar mahasiswa. *Jurnal Santiaji Pendidikan (JSP)*, *12*(1), 15–20. https://doi.org/10.36733/jsp.v12i1.3579

Cong, L., & Ironsi, C. S. (2025). *Integrating mobile learning and problem-based learning in problem-solving and critical thinking skills*. *2025*, 1–11. https://doi.org/10.1057/s41599-025-05397-4

Dira, A., Suana, W., & Permadi, D. (2024). Pengaruh model project-based learning dan pembelajaran berdiferensiasi terhadap kesadaran perubahan iklim siswa SMA. *DIFFRACTION: Journal for Physics Education and Applied Physics*, *6*(2), 91–104.

Ennis, R. H. (1996). *Critical thinking*. Prentice-Hall.

Febrianti, V. P. (2023). Bagaimana cara mengajarkan pemanasan global pada siswa sekolah menengah atas? *SIPTEK: Seminar Nasional Inovasi Dan Pengembangan Teknoologi Pendidikan* *1*(1), 1–13.

Ghofar, A., & Wicaksono, C. (2020). Lesson study untuk mengembangkan kualitas pembelajaran IPA di SMP berbasis think pair share yang dipadukan dengan modul. *Jurnal Pendidikan Ipa Veteran*, *4*(1), 2020.

Hadianta, L., Lutfianto, M., Hariyati, I., Kurnia Sari, I., & Chotimah, K. (2024). Penerapan lesson study untuk meningkatkan kemampuan berpikir kritis peserta didik melalui model pbl. *Jurnal Pi: Pendidikan Matematika Dan Integrasinya (2024) 3(2) 17-25*, *3*(2), 17–25.

Hake, R. R. (1999). *Analyzing change/gain scores*. AERA-D (American Educational Research Association's Division D, Measurement and Research Methodology). https://scispace.com/pdf/analyzing-change-gain-scores-2flqldd4zo.pdf

Handoyo, M. A. P., & Asri, N. P. (2023). Study on food loss and food waste: conditions, impact and solutions. *AGRITEPA: Jurnal Ilmu Dan Teknologi Pertanian*, *10*(2), 247–258. https://doi.org/10.37676/agritepa.v10i2.4579

Haris, A., Safaruddin, S., & Qamal, Q. (2023). Perubahan lingkungan fisik akibat dampak aktivitas tambang galian C di kabupaten barru. *Journal of Governance and Policy Innovation*, *3*(2), 54–60. https://doi.org/10.51577/jgpi.v3i2.471

Hobri. (2021). Metodologi penelitian pengembangan (aplikasi pada penelitian pendidikan matematika). Universitas Jember.

Kager, K., Kalinowski, E., Jurczok, A., & Vock, M. (2024). A systematic review of transparency in lesson study research: how do we report on the observation and reflection stages? *Frontiers in Education*, *9*(April), 1–19. https://doi.org/10.3389/feduc.2024.1322624

Keliat, N. R., Anggraini, P. P., & Tapilouw, M. C. (2025). The role of problem-based learning models with the lesson study approach in improving student's collaborative skills. *2024*, 18–40. https://doi.org/10.2991/978-2-38476-390-0_3

Keliat, N. R., Anggraini, P. P., & Trisianna, J. A. (2025). Science teacher's knowledge about lesson study as a professional investigation approach in learning. *Jurnal Penelitian Pendidikan IPA*, *11*(2), 350–357. https://doi.org/10.29303/jppipa.v11i2.8329

Kubiszyn, T. O. M., & Borich, G. (2016). *Educational testing and measurement: classroom application and practice* (10th ed.). John Wiley & Sons.

Lestari, D. D., Ansori, I., & Karyadi, B. (2017). Penerapan model pbm untuk meningkatkan kinerja dan kemampuan berpikir kritis siswa sma. *Diklabio: Jurnal Pendidikan Dan Pembelajaran Biologi*, *1*(1), 45–53. https://doi.org/10.33369/diklabio.1.1.45-53

Loyens, S. M. M., van Meerten, J. E., Schaap, L., & Wijnia, L. (2023). Situating higher-order, critical, and critical-analytic thinking in problem- and project-based learning environments: a systematic review. In *Educational Psychology Review* (Vol. 35, Issue 2). Springer US. https://doi.org/10.1007/s10648-023-09757-x

Najaah, L. S., & Amrulloh, M. (2022). Penerapan media pembelajaran interaktif global warming berbasis blended learning untuk meningkatkan pengetahuan dan sikap peduli lingkungan peserta didik sma. *Jurnal Jaringan Penelitian Pengembangan Penerapan Inovasi Pendidikan (Jarlitbang)*, 137–146. https://doi.org/10.59344/jarlitbang.v8i2.24

Nisak, E. F. K., & Susanti, E. (2023). Pengembangan e- LKPD perubahan lingkungan berbasis problem based learning untuk meningkatkan kemampuan pemecahan masalah peserta didik. *BioEdu*

Berkala Ilmiah Pendidikan Biologi, *12*(3), 683–694. https://doi.org/10.23887/jjpf.v14i1.75941

Nufutomo, T. K. (2022). Perubahan iklim sebagai ancaman ketahanan kualitas. *Jurnal Reka Lingkungan*, *10*(3), 188–200.

Ramadhan, A., & Mardin, S. (2023). Problem-based learning: improving critical thinking abilities, science literacy and students' independence in biology. *International Journal of Science and Research Archive*, *10*(2), 772–779. https://doi.org/10.30574/ijsra.2023.10.2.0982

Ratnaningsih, D., Suprapto, I., & Prayogi, R. (2022). Peningkatan kemampuan berpikir kritis mahasiswa dalam kerangka lesson study melalui model pembelajaran berbasis masalah. *Jurnal Elsa*, *20*(1), 14–29. https://doi.org/10.47637/elsa.v20i1.500

Sapitri, A., Tambunan, M. I. H., Lubis, R. E. ., & Arisetya, D. (2024). Pembelajaran Kultur Jaringan Tanaman Obat Berbasis Project Base Learning (PjBL) Terintegrasi Lesson Study: Plant Tissue Culture Learning Based on Project Based Learning (PjBL) Integrated Lesson Study. *BIODIK*, 10 (4), 682–690. https://doi.org/10.22437/biodik.v10i4.38756

Satwika, Y. W., Laksmiwati, H., & Khoirunnisa, R. N. (2018). Penerapan model problem based learning untuk meningkatkan kemampuan berfikir kritis mahasiswa. *3*, 7–12. https://doi.org/10.26740/jp.v3n1.p7-12

UNICEF. (2021). *The climate crisis is a child rights crisis*. UNICEF. https://www.unicef.org/reports/climate-crisis-child-rights-crisis

Wikurendra, E. A., Csonka, A., Nagy, I., & Nurika, G. (2024). Urbanization and Benefit of Integration Circular Economy into Waste Management in Indonesia: A Review. *Circular Economy and Sustainability*, *4*(2), 1219–1248. https://doi.org/10.1007/s43615-024-00346-w

Wulandari, F., Dewi, L. N., Kurniati, K., & Kuning, D. S. (2023). The implementation of lesson study model in micro teaching. *Jurnal Smart*, *9*(1), 55–61. https://doi.org/10.52657/js.v9i1.2123

Yildiz, A., & Baltaci, S. (2017). Reflections from the lesson study for the development of techno-pedagogical competencies in teaching fractal geometry. *European Journal of Educational Research*, *volume-6-2* (volume6-issue1.html), 41–50. https://doi.org/10.12973/eu-jer.6.1.41

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987

Zubaidah, S., Corebima, A. D., Mahanal, S., & Mistianah. (2018). Revealing the relationship between reading interest and critical thinking skills through remap GI and remap jigsaw. *International Journal of Instruction*, *11*(2), 41–56. https://doi.org/10.12973/iji.2018.1124a