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Developing DL-STEM-PjBL Teaching Competence through Lesson Study in Preservice Elementary Teachers

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ABSTRACT

This study evaluated the development of preservice elementary teachers' competence in designing and implementing integrated pedagogical deep learning (DL), science, technology, engineering, and mathematics (STEM), and project-based learning (PjBL) through lesson study. A descriptive evaluative approach with a single-group implementation design involved 104 preservice elementary teachers purposively selected from a Professional Teacher Education Program at Universitas Muhammadiyah Malang, Indonesia, focusing on integrated science and social studies (IPAS). Orientation and coaching were followed by three lesson study cycles involving collaborative planning, observed teaching, reflection, and follow-up improvement. Reported evidence comprised understanding tests, lesson plan and teaching practice assessments, and reflection scores, supported by instructional documentation. Mean understanding increased from 63 to 75, while the proportion in the moderate or high categories increased from 2.9% to 85.6%. Mean reflection quality increased from 1.5 to 3.5 on a five-point scale. Mean lesson plan and teaching practice scores each increased from 65 in Cycle 1 to 75 in Cycle 2 and 85 in Cycle 3. These descriptive findings support considering lesson study as a structured professional learning framework for integrated DL-STEM-PjBL instruction. However, the single-group design and limitations in the available measurement documentation preclude independent causal attribution or conclusions about pupils' learning outcomes.

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INTRODUCTION

Pedagogical deep learning (DL) has become an increasingly important orientation in Indonesian primary and secondary education. DL refers to deep learning, rather than deep learning in the machine-learning sense. DL emphasizes three mutually reinforcing learning qualities: mindful learning, meaningful learning, and joyful learning (Dewi & Dalimunthe, 2026; Nafi & Faruq, 2025; Nurhasanah et al., 2025). These qualities are expected to move students beyond memorization toward conceptual understanding, active engagement, critical reasoning, and the ability to connect scientific concepts with daily life (Fitrah et al., 2025; Fredy et al., 2026; Wang, 2026). However, such expectations require teachers who can design learning experiences carefully, because the goals of deep learning may fail when the approach is treated only as a slogan rather than as a pedagogical design principle.

STEM education also requires teachers to facilitate learning as an inquiry-driven and problem-solving process. In STEM-oriented classrooms, students observe real-life phenomena, identify authentic problems, conduct investigations, design solutions, and produce evidence-based products (Halawa et al., 2024; Hemtasin et al., 2026; Leung, 2023; Priemer et al., 2020; Suherman et al., 2025). These characteristics align closely with project-based learning (PjBL), in which students formulate essential questions, plan projects, manage schedules, monitor progress, evaluate products, and reflect on both process and outcomes. PjBL is not merely a craft-making activity; it is a structured model for developing scientific reasoning, creativity, collaboration, communication, perseverance, and responsibility (Arango-Caro et al., 2025; Sánchez-García & Reyes-de-Cózar, 2025; Schutte et al., 2025; Sukackė et al., 2022).

The integration of DL, STEM, and PjBL is pedagogically promising because DL provides the learning principles, STEM provides the interdisciplinary content and engineering design orientation, and PjBL provides the instructional syntax. In an integrated DL-STEM-PjBL design, the principles of mindful, meaningful, and joyful learning must be embedded in each phase of project-based STEM learning. The essential question should be scientific, contextual, and sufficiently complex; project planning should be evidence-based; and product development should involve investigation, testing, revision, and reflection. This integration is especially relevant for the Professional Teacher Education Program (*Program Profesi Guru*/PPG), where preservice teachers must be prepared to design and conduct future-oriented learning.

Despite the conceptual potential of DL-STEM-PjBL, many preservice teachers have limited prior understanding of the three components as an integrated instructional framework. They may know DL, STEM, or PjBL separately, yet still face difficulty translating them into a coherent lesson

plan and classroom practice. Therefore, a structured professional learning model is needed. Lesson study offers such a model through collaborative planning, observed teaching, reflective discussion, and follow-up improvement (Bufasi et al., 2024; Coenders & Verhoef, 2019; Erbilgin & Robinson, 2025; Kager et al., 2023; Wake et al., 2016). Within the PPG context, lesson study can function as an induction process that strengthens preservice teachers' competence through open plan, open class, open see, and continuous revision.

Based on this gap, this study aimed to examine the implementation of lesson study in strengthening preservice teachers' competence to design and conduct integrated DL-STEM-PjBL learning. Specifically, the study focused on students' understanding of DL-STEM-PjBL, the quality of lesson plans, the quality of teaching practice, and the development of reflective competence across lesson study cycles.

RESEARCH METHODS

This study used a descriptive evaluative approach with a single-group implementation design to examine competence development during a lesson study intervention. Quantitative assessment results provided the main evidence, while lesson documents, observation, reflection, and video documentation provided contextual records of the professional learning process. The intervention comprised orientation and coaching followed by three lesson study cycles involving open plan, open class, open see, and follow-up improvement (Figure 1). The three-cycle sequence enabled initial implementation, revision, and further implementation within the observed program. It was not treated as a universal minimum number of cycles. Because the available account does not specify a separate qualitative coding procedure or integration of qualitative and quantitative findings, the study is reported as a descriptive evaluation rather than as a fully specified mixed-methods investigation. No comparison group was included; the analysis therefore describes within-group development without estimating an independent causal effect.



Figure 1. Lesson study cycle used to strengthen DL-STEM-PjBL teaching competence

The population consisted of 204 students enrolled in the Professional Teacher Education Program (Program Profesi Guru/PPG) at the Faculty of Education, Science, and Humanities,

Universitas Muhammadiyah Malang. The sample comprised 104 preservice elementary teachers selected purposively based on their involvement in teaching integrated science and social studies (IPAS) in Grades 3, 4, and 5. Data sources included pre- and post-tests, lesson plan assessments, teaching practice observations, reflection scores, questionnaires, and video documentation. The reported outcomes concern the participating teachers' competence and do not measure elementary pupils' learning gains.

The four assessed dimensions were understanding of DL-STEM-PjBL integration, lesson plan quality, teaching practice quality, and reflective competence. Understanding was assessed before and after coaching through tests addressing the nature, objectives, and procedures of integrated DL-STEM-PjBL. Lesson plan assessment considered the explicit integration of DL principles, STEM orientation, and PjBL syntax. Teaching practice assessment used observation sheets and video analysis. Lesson plan and teaching practice scores were reported across three cycles. Reflection was assessed on a five-point scale covering self-evaluation, identification of obstacles, recognition of good practices, and formulation of follow-up plans, with results available for two reflection sessions. Thus, the four dimensions were not measured on an identical schedule. Understanding, lesson plan, and teaching practice scores were categorized as very low (50–60), low (61–70), moderate (71–80), high (81–90), and very high (91–100). Reflection categories were very low (1.0–2.0), low (2.1–3.0), moderate (3.1–4.0), and high (4.1–5.0). These are the categories used for the reported scores; the reflection scale has different category labels and must be interpreted separately. Analysis used reported means, differences in means, and category frequencies and percentages. Category changes were interpreted at group level rather than as matched individual transitions. Standard deviations and observed minimum–maximum values were not available in the reported summaries and were not estimated from grouped data.

RESEARCH RESULTS

The implementation of lesson study in this study was examined through several indicators of teaching competence, namely students' understanding of DL-STEM-PjBL integration, reflective competence, lesson plan quality, and teaching practice quality. These indicators represent the main stages of professional competence development in the lesson study cycle, beginning with orientation and coaching, followed by open plan, open class, open see, and follow-up improvement. The data were processed descriptively to show changes in competence before and after the intervention, as well as across the learning cycles.

Table 1 summarizes the reported changes in the four competence dimensions. Understanding was compared before and after coaching, reflection across two sessions, and lesson

plan and teaching practice quality between Cycles 1 and 3. The differences refer to each indicator's own scale and assessment schedule and should not be interpreted as directly comparable effect sizes.

Table 1. Summary of competence development after lesson study intervention

Indicator	Initial score	Final score	Gain	Interpretation
Understanding of DL-STEM-PjBL	63	75	+12	Low to moderate
Reflection quality	1.5	3.5	+2.0	Very low to moderate
Lesson plan quality	65	85	+20	Low to high
Teaching practice quality	65	85	+20	Low to high

Source: Study data summaries.

Table 1 shows higher final mean scores for all four dimensions. Understanding of DL-STEM-PjBL increased from 63 to 75, a difference of 12 points and a shift in the mean from the low to moderate category. Mean reflection quality increased from 1.5 to 3.5 on the five-point scale, shifting from very low to moderate. These results describe changes during the intervention without identifying the separate contribution of coaching, collaborative planning, or reflection.

Mean lesson plan and teaching practice scores each increased from 65 in Cycle 1 to 85 in Cycle 3, a difference of 20 points on their respective reported scales. Both means shifted from low to high. The identical aggregate changes do not establish a participant-level association between the two dimensions.

To provide a more detailed picture of conceptual improvement, students' understanding of DL-STEM-PjBL integration was analyzed based on score categories before and after coaching. This analysis is important because the mean score alone does not fully describe how students shifted from lower to higher levels of understanding. The distribution of students across score categories is presented in Table 2.

Table 2. Distribution of students' understanding before and after coaching

Score range	Category	Pre-test n (%)	Post-test n (%)	Direction of change
50-60	Very low	45 (43.3%)	0 (0.0%)	Decreased
61-70	Low	56 (53.8%)	15 (14.4%)	Decreased
71-80	Moderate	3 (2.9%)	79 (76.0%)	Increased
81-90	High	0 (0.0%)	10 (9.6%)	Increased
91-100	Very high	0 (0.0%)	0 (0.0%)	Stable
Total	-	104 (100%)	104 (100%)	-

Source: Processed from pre-test and post-test data.

As shown in Table 2, there was a clear shift in students' understanding after the coaching process. Before coaching, 45 students, or 43.3%, were in the very low category, while 56 students, or 53.8%, were in the low category. This means that most students initially had limited

understanding of the nature, objectives, and procedures of DL-STEM-PjBL integration. Only three students, or 2.9%, reached the moderate category, and none reached the high or very high category.

After coaching, no participants were classified as very low, 15 (14.4%) were classified as low, 79 (76.0%) as moderate, and 10 (9.6%) as high. The combined proportion in the moderate or high categories increased from 3 of 104 (2.9%) to 89 of 104 (85.6%). No participant was classified as very high. These distributions indicate a group-level shift toward higher categories; they do not identify the individual transitions between categories.

Reflective competence was also analyzed because reflection is a central component of lesson study. Through open see, students were expected to evaluate their lesson plans and teaching practices based on evidence from classroom implementation. The development of reflective competence across two reflection sessions is presented in Table 3.

Table 3. Development of reflective competence across two reflections

Score range	Category	Reflection 1 n (%)	Reflection 2 n (%)	Interpretation
1.0-2.0	Very low	100 (96.2%)	0 (0.0%)	Lower frequency
2.1-3.0	Low	4 (3.8%)	4 (3.8%)	Same count at both sessions
3.1-4.0	Moderate	0 (0.0%)	100 (96.2%)	Higher frequency
4.1-5.0	High	0 (0.0%)	0 (0.0%)	No participants in this category
Total	-	104 (100%)	104 (100%)	-

Source: Reported reflection scores (n = 104 at each assessment).

In the first reflection session, 100 of 104 participants (96.2%) were classified as very low and four (3.8%) as low. The reported mean was 1.5 on the five-point scale. The score distribution indicates low assessed reflection quality at the first session; specific weaknesses in participants' reasoning cannot be established from category frequencies alone.

In the second reflection session, 100 participants (96.2%) were classified as moderate and four (3.8%) as low, with a mean score of 3.5. No participants were classified as very low or high. The identical number in the low category at both assessments does not establish that these were the same four individuals. Overall, the reported scores indicate higher reflection quality at the second session.

The next analysis focuses on the development of lesson plan quality and teaching practice quality across three cycles. These two indicators are essential because they show whether students were able to transform conceptual understanding and reflective feedback into improved pedagogical performance. The progression of both indicators is presented in Table 4.

Table 4. Progression of lesson plan and teaching practice quality across cycles

Cycle	Lesson plan mean	Lesson plan category	Teaching practice mean	Teaching practice category	Main improvement focus
Cycle 1	65	Low	65	Low	Basic understanding and alignment of DL, STEM, and PjBL syntax
Cycle 2	75	Moderate	75	Moderate	Clearer essential questions, project planning, and student activities
Cycle 3	85	High	85	High	Coherent integration, stronger facilitation, and reflective follow-up

Source: Processed from lesson plan and teaching practice score data.

Table 4 presents the reported mean lesson plan and teaching practice scores across three cycles. Both means were 65 in Cycle 1 (low), 75 in Cycle 2 (moderate), and 85 in Cycle 3 (high). The reported instructional focus progressed from basic alignment of DL, STEM, and PjBL to clearer project planning and then more coherent integration and facilitation.

These cycle-level summaries describe the direction of assessed development. They do not quantify which rubric components improved most or establish that every participant followed the same trajectory. The instructional focus listed in Table 4 provides context for the cycles rather than separate quantitative evidence of changes in specific teaching behaviors.

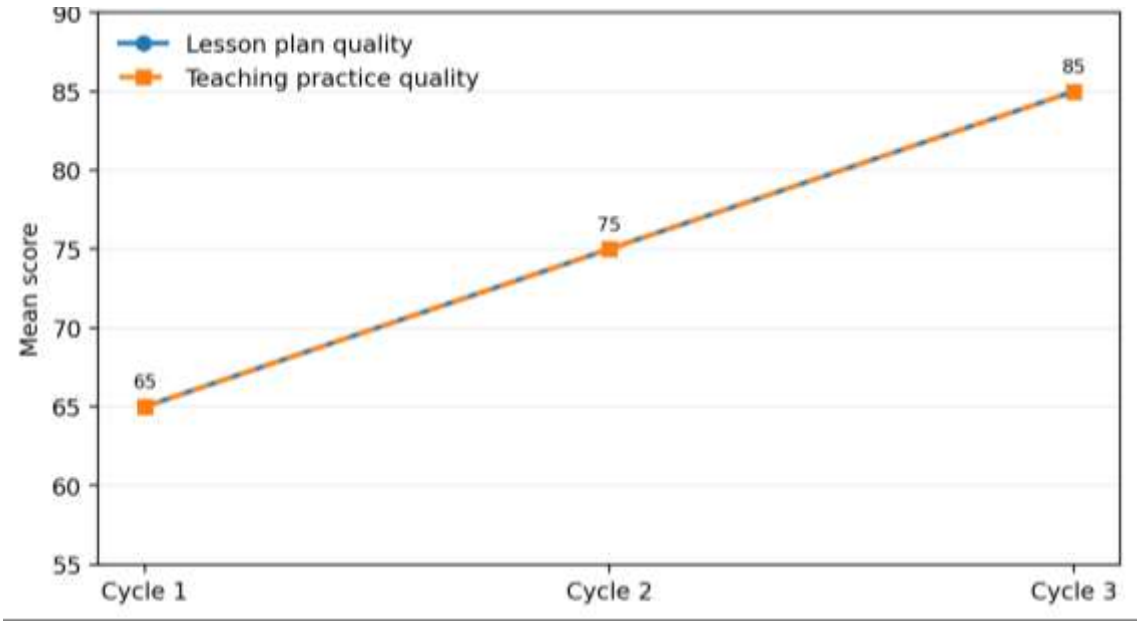


Figure 2. Mean lesson plan and teaching practice scores across three lesson study cycles

Figure 2 summarizes the cycle-based development of lesson plan and teaching practice quality. The two series overlap because their reported means are identical: 65, 75, and 85.

Understanding and reflection are retained in Tables 2 and 3 because they were assessed at different occasions and cannot be presented as three-cycle trajectories from the available data.

To synthesize the most important findings, Table 5 presents the key data insights from the study. This table connects the evidence from the quantitative results with its meaning for PPG practice. The synthesis is intended to clarify the practical implications of the lesson study intervention for strengthening pre-service teacher competence.

Table 5. Summary of findings and implications for teacher preparation

Key finding	Evidence	Meaning for PPG practice
Higher understanding after coaching	Mean understanding rose from 63 to 75	Conceptual preparation can be included before planning and teaching practice.
Higher reflection scores	Reflection score rose from 1.5 to 3.5	Structured reflection can be included in professional learning; its separate effect was not estimated.
Parallel planning and practice means	Both reached 85 in Cycle 3	Review lesson planning and teaching practice together without assuming an individual-level association.
Final means below the highest applicable category	Understanding 75; reflection 3.5/5; planning and practice 85	Further mentoring may be useful; the required duration was not established.

Source: Synthesized from the quantitative results.

Table 5 summarizes the practical interpretation of the descriptive findings. Understanding scores increased from 63 to 75 following coaching, while reflection scores increased from 1.5 to 3.5 across the two reflection sessions. These patterns support considering conceptual preparation and structured reflection within teacher preparation, but do not establish their separate effects.

Lesson plan and teaching practice means each reached 85 in Cycle 3. Their parallel trajectories support reviewing planning and implementation together in professional learning. Final mean scores remained below the highest category applicable to each scale. Further mentoring may therefore be useful, although the present evaluation does not determine the additional duration or number of cycles required.

Overall, the reported results document higher scores in understanding, reflection, lesson planning, and teaching practice during the lesson study program. The findings provide descriptive evidence for discussing lesson study as a professional learning framework within PPG, with interpretation bounded by the single-group design and the available aggregate data.

DISCUSSION

The findings document competence development during a lesson study program for preservice elementary teachers integrating DL, STEM, and PjBL in IPAS instruction. Mean understanding increased from 63 to 75, and the proportion classified as moderate or high increased from 2.9% to 85.6%. This pattern is consistent with the role of conceptual preparation in coherent

instructional design, although the evaluation does not isolate the effect of orientation and coaching from other learning experiences (He et al., 2023; Nordine et al., 2021).

Mean reflection scores increased from 1.5 to 3.5 on a five-point scale. The accompanying category shift suggests stronger assessed reflection at the second session. In lesson study, reflection can connect classroom observation with subsequent instructional revision. However, without systematically coded reflection excerpts, the present scores cannot establish which forms of reasoning changed or how reflection influenced later performance. The interpretation is therefore consistent with, but does not directly test, accounts of structured reflection as a professional learning mechanism (Iqbal et al., 2021; Kager et al., 2022; Kyriakides et al., 2026; Vogelsang et al., 2025).

Lesson plan and teaching practice means followed the same trajectory across three cycles, increasing from 65 to 75 and then 85. This pattern is consistent with progressive development during repeated planning, implementation, and reflection. Nevertheless, identical aggregate means do not demonstrate a participant-level relationship between planning and teaching quality, and the data do not identify the relative influence of feedback, practice, topic familiarity, or other program experiences.

Final mean scores remained below the highest category applicable to each assessment scale. Understanding, lesson planning, and teaching practice used five categories, whereas reflection used four; the absence of a "very high" reflection category should therefore not be interpreted as a performance finding. Continued professional learning may help consolidate the complex decisions involved in project design, inquiry facilitation, assessment, and reflection. This interpretation aligns with literature emphasizing sustained and collaborative teacher development (Darling-Hammond et al., 2020; de Jong et al., 2023; Guo et al., 2025; Hu & Chan, 2025; O'Connor & Park, 2023; Tan et al., 2025).

The study contributes a descriptive account of lesson study as a framework for connecting conceptual preparation with lesson planning, teaching practice, and reflection in elementary IPAS teacher preparation. Its practical contribution is the joint consideration of these four competence dimensions within an integrated DL-STEM-PjBL program. Future evaluations should examine whether competence development is sustained and whether it is associated with pupils' science learning and project outcomes.

Several limitations constrain interpretation. The single-group design and purposive sample from one institution limit causal attribution and transferability. The available documentation does not establish whether all observed teaching involved peers or elementary pupils, nor does it specify

school sites, group organization, or role rotation; transfer to ordinary classroom teaching therefore remains uncertain. Instrument validation, reliability, inter-rater agreement, and a formal qualitative triangulation procedure are not documented in the available account. Only aggregate means and category counts are reported, without standard deviations or observed score ranges. Differences in topics or assessment conditions across cycles cannot be ruled out. Finally, the three-cycle observation period does not establish long-term retention, and the different assessment schedules prevent synchronized four-indicator cycle comparisons. These limitations qualify the findings without negating the reported descriptive changes.

CONCLUSION

During the lesson study program, the participating preservice elementary teachers showed higher assessed competence in integrated DL-STEM-PjBL instruction. Mean understanding increased from 63 to 75, and mean reflection increased from 1.5 to 3.5 on a five-point scale. Mean lesson plan and teaching practice scores each increased from 65 in Cycle 1 to 85 in Cycle 3. These results support considering lesson study as a structured framework linking conceptual preparation, collaborative planning, teaching practice, and reflection within PPG. The findings describe development within the participating group and do not establish that lesson study alone caused the changes. Further evaluation is needed to establish measurement consistency, sustained competence, and implications for pupils' learning.

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CONFLICTS OF INTEREST

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

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

N. Nurwidodo: conceptualization, methodology, supervision, project administration, writing - original draft, and writing - review & editing; **I. Hindun:** investigation, resources, data curation, formal analysis, visualization, writing - original draft, and writing - review & editing.

DECLARATION OF THE USE OF AI

During the preparation of this work, the authors used OpenAI's ChatGPT to support English language alignment, improve clarity, and reduce typographical errors. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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