International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 12; Issue: 5; May 2025
Website: www.ijrrjournal.com
E-ISSN: 2349-9788; P-ISSN: 2454-2237
Research Paper

The Effect of Problem-Based Learning Integrated with Collaborative Learning on Metacognitive Skills and Biology Concept

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DOI: https://doi.org/10.52403/ijrr.20250523

ABSTRACT

Conventional learning methods are still widely applied in schools, often limiting students' ability to absorb material effectively. The use of a single instructional model tends to result in unequal student engagement, with only high-achieving learners demonstrating significant development. This study investigates the effect of a Problem-Based Learning (PBL) model integrated with Collaborative Learning (CL) on students' metacognitive skills and achievement of high school student biology concepts. Quasi-experimental design with a pretest-posttest control group was employed, involving students from Mumbulsari Public High School, Jember, during the odd semester of the 2024/2025 academic year. Sampling was conducted using the random sampling method after normality, homogeneity, and Least Significant Difference (LSD) post hoc tests were administered. Three classes were assigned: XI-4 (experimental group), XI-7 (negative control), and XI-5 (positive control). Data collection techniques included observation, interviews, documentation, inventories, and tests. The results showed that the experimental group outperformed both control groups in terms of pretest and posttest scores. Statistical analysis using ANCOVA revealed a significant effect ($p = 0.000 < 0.05$), indicating that the integrated PBL-CL model positively impacted students' metacognitive skills and learning outcomes. These findings were further supported by LSD test results, confirming the model's effectiveness. This study contributes valuable insights and offers innovative alternatives for enhancing science education through collaborative, student-centered learning approaches.

Keywords: Problem-based learning, Collaborative learning, Metacognitive skill, Achievement of biology concepts

INTRODUCTION

Metacognitive skills are a vital component of the learning process, as they extend beyond content mastery to include an individual's capacity to comprehend their own cognitive strategies, learning processes, and adaptability within dynamic learning environments. Strengthening these skills is widely recognized as a key contributor to enhancing the quality of human resources in Indonesia. High-quality education plays a pivotal role in developing individuals who are well-prepared to navigate the complexities of the modern era.[5] Among the factors influencing educational quality, the instructional approach adopted in classrooms holds significant weight. Despite evolving pedagogical trends, teacher-centered instruction remains prevalent in many schools, often resulting in minimal student engagement and shallow conceptual understanding. [11]

Educators bear a critical responsibility in designing and implementing learning models that foster meaningful student engagement and improved academic outcomes. Learner-centered methodologies are considered more effective in promoting active participation, especially when coupled with collaborative problem-solving strategies. One such model is Problem-Based Learning (PBL), which encourages learners to develop solutions based on evidence, inquiry, and critical thinking.[15] However, PBL is not without limitations particularly among students with low academic motivation, who may exhibit passivity and struggle to fully engage in the learning process.[3]

To address these challenges, the integration of PBL with Collaborative Learning (CL) has been proposed as a complementary approach. Research suggests that PBL nurtures students' abilities to independently plan, evaluate, and regulate their thinking processes.[10] Meanwhile, Collaborative Learning fosters interactive group dynamics that support deeper understanding through mutual dependence and collective responsibility.[1]

The integration of PBL and CL is anticipated to enhance both metacognitive skills and students' conceptual grasp particularly in science education contexts such as biology. This collaborative framework empowers students to draw not only from personal learning experiences but also from peer perspectives, thereby enriching their cognitive processes. Furthermore, it cultivates reflective practices such as planning, monitoring, and evaluating one's learning progression.[13] Collaborative problem-solving also serves as a bridge between theoretical concepts and real-world application, reinforcing students' comprehension and long-term mastery of subject matter.

RESEARCH METHODS

This study was carried out at Mumbulsari Public High School, located at No. 62 Drs. Soebandi Street, Karang Sirih Hamlet, Suco Village, Mumbulsari District, Jember Regency, East Java Province. The research took place in November, during the odd semester of the 2024/2025 academic year, and involved all 11th-grade students, comprising a total of five classes.

Sample selection was based on normality and homogeneity tests to ensure that the data distribution met the necessary assumptions. This was followed by the Least Significant Difference (LSD) test to determine the appropriate sample classes. Subsequently, the random sampling technique was employed to assign the experimental and control groups (positive or negative).

The research applied a quasi-experimental method with a pretest-posttest control group design. Three classes were involved in the study: class XI-4 as the experimental group, class XI-7 as the negative control group, and class XI-5 functioned as the positive control group. The combined sample from all three classes included 105 students. The research design is structured as follows.

Table 1. Quasi-Experimental Research Design

Class	Pre-Test	Treatment	Post-Test
E	P_1	Y	P_2
C1(-)	O_1	X_1	O_2
C2 (+)	R_1	Z_2	R_2

Explanation:

E : Experimental Group
C1(-) : Control Group 1 (without treatment)
C2(+) : Control Group 2 (with treatment)
P1 : Pre-test in the experimental group
P2 : Post-test in the experimental group
O1 : Pre-test in Control Group 1
O2 : Post-test in Control Group 1
R1 : Pre-test in Control Group 2
R2 : Post-test in Control Group 2
Y : Problem-Based Learning model integrated with Collaborative Learning
X : Conventional teaching model

Z : Problem-Based Learning (PBL) model

The assessment of students' metacognitive skills and achievement of biology concepts was conducted in two stages: a pretest and a posttest. Metacognitive skills were measured using a questionnaire adapted from Schraw and Dennison's framework, consisting of 35 items. Meanwhile, conceptual understanding in biology was evaluated using test items based on the human circulatory system topic, comprising a total of 15 questions, 10 multiple-choice items and 5 essay questions.

The pretest and posttest results for both metacognitive skills and conceptual understanding were analyzed using Analysis of Covariance (ANCOVA). If the analysis yielded a statistically significant result, a follow-up test using Least Significant Difference (LSD) was conducted. The students' scores were calculated based on a predetermined formula and assessment criteria, as outlined below.

Score Achievement = (number of scores)/ (maximum score) x 100

Table 2. Metacognitive Skills Assessment Criteria

Average Score Interval	Metacognitive Skill Category
0–20	Poor
21–40	Not Yet Developed
41–60	Beginning to Develop
61–80	Well Developed
81–100	Very Well Developed

Green, as cited in (Saenab *et al*., 2019)

Tabel 3. Achievement of Biology Concept Assessment Criteria

Average Score Interval	Mastery Level
X < 40%	Poor
40% ≤ X < 55%	Fair
55% ≤ X < 70%	Moderate
70% ≤ X < 85%	Good
X ≥ 85%	Excellent

(Agustinus & Yusuf, 2023)

RESULT

1. Metacognition Skills Data Analysis

The measurement of students' metacognitive skills in this study utilized the Metacognitive Awareness Inventory (MAI), consisting of 35 items covering three key indicators: planning, monitoring, and evaluation. The pretest and posttest scores from both the experimental and control groups were analyzed using Analysis of Covariance (ANCOVA) to determine whether the applied instructional model had a significant effect on students' metacognitive skills. The results of the ANCOVA test for students' metacognitive skills are presented in Table 4.

Table 4. ANCOVA test results of metacognition skills of class E, K1(-) and K2(+)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	8522.559^{A}	3	2840.853	70.831	.000
Intercept	3496.016	1	3496.016	87.167	.000
Pre-test_MAI	52.540	1	52.540	1.310	.255
Model_Pembelajaran	8519.906	2	4259.953	106.214	.000
Error	4050.831	101	40.107		
Total	432095.000	105			
Corrected Total	12573.390	104			
a. R Squared = .678 (Adjusted R Squared = .668)					

Based on Table 4, The analysis indicated a significance value (Sig.) of 0.000 ($p < 0.05$), suggesting that the variation in learning models applied across the sample classes had a statistically significant impact on students' metacognitive skill development. Subsequently, a post hoc analysis using the Least Significant Difference (LSD) method was conducted. The results of the LSD test, comparing the experimental group (E), control group 1 (K1), and control group 2 (K2), are presented in Table 5 below.

Table 5. LSD test results on metacognition skills of class E, K1 (-) and K2 (+)

Class	Mean	Average Pre-test ± SD	Average Post-test ± SD	Difference	Sig.	Notation
E	74,2	45.5±6.1	74.2±7.8	28,7	0,000	a
K2 (+)	63,23	43.7±6.3	63.3±10.2	19,6	0,000	b
K1 (-)	52,2	46.1±6.7	52.2±7.7	6,1	0,000	c

Based on Table 5, the results of the Least Significant Difference (LSD) test indicate a significance value of 0.000 ($p < 0.05$), which signifies a statistically significant difference between the groups. This suggests that the experimental class differs significantly from both control group 1 (negative) and control group 2 (positive), and vice versa. Moreover, the LSD notation results show that the experimental group yielded the most substantial effect on improving students' metacognitive skills compared to the other two groups.

2. **Analysis of Students' Biology Concept in the Cognitive Domain**

The data on students' biology concept achievement were obtained from the pre-test conducted prior to the implementation of the learning models and the post-test administered afterward. These assessments focused on evaluating students' conceptual understanding within the cognitive domain. The pre-test and post-test scores were analyzed using Analysis of Covariance (ANCOVA) to determine whether differences in instructional models had a statistically significant effect on students' cognitive learning outcomes across all sample classes. The ANCOVA results comparing students' pre-test and post-test scores are presented in Table 6 below.

Table 6. ANCOVA Results on Biology Concept in Classes E, K1(-), and K2(+)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	21042.407a	3	7014.136	72.512	.000
Intercept	4044.857	1	4044.857	41.816	.000
Pretest_Penguasaan_Konsep	1010.807	1	1010.807	10.450	.002
Kelas_Model_Pembelajaran	20481.846	2	10240.923	105.870	.000
Error	9769.821	101	96.731		
Total	372984.000	105			
Corrected Total	30812.229	104			
a. R Squared = .683 (Adjusted R Squared = .674)					

The results of the Analysis of Covariance (ANCOVA) for biology concept achievement showed a significance value of 0.000 ($p < 0.05$) for the learning model. This indicates a statistically significant effect of the different instructional approaches applied across the sample classes on students' biology concept achievement. To further investigate these findings, a Least Significant Difference (LSD) post hoc test was conducted. The results of the LSD test on students' biology concept achievement are presented in Table 7 below.

Table 7. LSD Results on Students' Biology Concept in Classes E, K1(-), and K2(+)

Class	Mean	Average Pre-test± SD	Average Post-test ± SD	Difference	Sig.	Notation
E	70,60	32.5±5.5	70.6±10.8	38,1	0,000	a
K2 (+)	62,54	32.4±4.7	62.5±9.6	30,2	0,000	b
K1 (-)	38,11	33.1±5.9	38.1±10	5,0	0,001	c

Based on Table 7, the results of the Least Significant Difference (LSD) post hoc test showed a significance value of 0.000 ($p < 0.05$). This indicates that there were statistically significant differences among the three groups analyzed. The experimental class differed significantly from both control group 1 (K1) and control group 2

(K2), and the reverse was also true. Furthermore, the LSD notation revealed that the experimental class demonstrated the most substantial positive impact on students' biology concept achievement. These findings confirm that the instructional model of Problem-Based Learning (PBL) integrated with Collaborative Learning is more effective than either conventional teaching or PBL without collaboration.

DISCUSSION

1. The Effect of the Problem-Based Learning Model Integrated with Collaborative Learning on Metacognitive Skills

Based on the ANCOVA analysis of metacognitive skills data in Table 4, a significance value of 0.000 ($p < 0.05$) was obtained, indicating a significant effect on metacognitive skills scores after the implementation of different teaching models across all research class samples. The most substantial impact was observed in the experimental class utilizing the Problem-Based Learning (PBL) model integrated with Collaborative Learning (CL). This finding is reinforced by the LSD test results in Table 5, which show a significance value of 0.000 ($p < 0.05$), indicating significant differences between the experimental class and both control classes. According to the LSD notation, the experimental class falls into category "a," signifying the most positive impact on enhancing students' metacognitive skills.

This positive influence is indirectly related to the successful implementation of a teaching model aligned with the syntax and Student Worksheets (LKPD) designed by the teacher. The integration of two teaching models, namely PBL and CL, requires students to regulate their own thinking processes in solving encountered problems. The PBL model, based on real-world problem-solving, combined with the CL model that encourages cooperation and discussion among students, creates a more active learning environment. [7-16] Strong metacognitive skills enable students to become more independent and directed learners. [8]

PBL can facilitate the development of students' metacognitive skills, as this model encourages students to plan solutions, examine alternatives, and evaluate outcomes, all of which involve self-regulation and monitoring of their thinking processes. [10] Collaborative learning model is a group-based teaching model that encourages students to interact and learn together to enhance their understanding.[15] The main principle of collaborative learning is positive interdependence among group members, which promotes individual responsibility and simultaneous teamwork.[1]

Collaborative learning also fosters a sense of care among students, making them more willing to ask peers about material they do not understand and to engage in discussions or collaborations in solving problems provided by the teacher.[9] This allows students to compare their reasoning with that of peers and acquire knowledge. Implementation of these two teaching models can positively influence increasing students' awareness and learning motivation, as each teaching model offers different approaches to stimulate students' self-awareness and reflection on their learning processes.[17]

2. The Effect of the Problem-Based Learning Model Integrated with Collaborative Learning on Conceptual Understanding of Biology in the Cognitive Domain

Based on the ANCOVA data analysis results presented in Table 6, a significance value of 0.000 ($p < 0.05$) was obtained, indicating a significant effect on students' mastery of biological concepts after the application of different learning models in each class group. The most significant effect was found in the experimental class that implemented the Problem-Based Learning (PBL) model integrated with Collaborative Learning (CL). This finding is reinforced by the results of the Least Significant

Difference (LSD) test presented in Table 7, which shows a significance value of 0.000 ($p < 0.05$), indicating a significant difference between the experimental class and control classes 1 (-) and 2 (+), both directly and conversely. Additionally, based on the LSD test notation, the experimental class falls into category "a".

PBL model can enhance students' engagement in finding solutions and applying biological concepts in real contexts.[2] The CL model encourages student interaction, strengthening concept understanding through group discussions.[15] Collaborative learning enhances students' ability to solve complex problems through idea exchange and joint improvement.[4] Conversely, the control class 1 (-), which employed the conventional teaching model, tended to be more teacher-centered, with students passively receiving information. Student activity in the classroom is influenced by the quality of teaching.[6] Students tend to be passive if the method used is predominantly lecturing. Therefore, although there was improvement in control class 1 (-), the increase was relatively smaller. Meanwhile, in control class 2 (+), which used PBL without CL, there was a significant increase in scores, but still lower compared to the experimental class.

Based on the above description, the PBL model focuses on solving real problems or finding solutions to existing issues, thereby training students' thinking skills. One weakness of the PBL model is the lack of student understanding of the problems to be solved, which can decrease their interest in learning. [18] To address this, the CL learning model can be used to enhance students' learning interest. A prominent syntax in the CL learning model to address this is the second syntax (student organization).

Group formation in the CL learning model has a heterogeneous structure, with each group having different abilities. [12] The aim is to encourage the exchange of ideas from various perspectives, which relates to the third syntax of the CL learning model, namely individual and group investigation. Collaboration in this learning emphasizes team dynamics and sharing knowledge from various viewpoints, thereby broadening the knowledge and insights of group members. [9] Supporting the implementation of this, in the preparation of Student Worksheets (LKPD) as exercises, question number 4 requires all group members to propose one solution to the problem of hypertension. Through this question, interaction and exchange of opinions among students can occur naturally. This stage reflects how students actively express their thoughts, both individually and in group discussions.[12]

The existence of equal interaction within the group can facilitate students in understanding the material concepts taught through problem-based practice questions with student collaboration. Through this process, students will understand and be able to apply the material in real-life contexts, ultimately strengthening their mastery of the concepts taught. This indicates that the application of the PBL model integrated with CL has a greater influence on improving students' biology concept mastery compared to conventional learning models or PBL without CL. The integration of both learning models, namely PBL and CL, can significantly enhance students' mastery of biology concepts. PBL emphasizes solving real problems, while CL encourages students to voice opinions, collaborate, and create a more active and dynamic learning atmosphere.

CONCLUSION

The findings of this study conclude that the implementation of the Problem-Based Learning (PBL) model integrated with Collaborative Learning (CL) significantly influences students' metacognitive skills and conceptual understanding in biology. This is evident from the analysis of pretest and posttest results, which revealed that the experimental class achieved higher average scores compared to control classes 1 and 2. The covariance analysis (ANCOVA) yielded a significance value of 0.000 (p <

0.05), confirming that the applied instructional model had a statistically significant effect. Among the models tested, the integrated PBL and CL approach produced the most substantial impact, particularly in the experimental group. These findings are further supported by the results of the LSD post hoc test, which also showed a significance value below 0.05 and placed the experimental class within the "a" category, indicating a clear and meaningful difference from the other groups.

Declaration by Authors

Acknowledgement: None

Source of Funding: None

Conflict of Interest: No conflicts of interest declared.

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How to cite this article: Miftahul Jannah, Suratno, Bea Hana Siswati. The effect of problem-based learning integrated with collaborative learning on metacognitive skills and biology concept. *International Journal of Research and Review*. 2025; 12(5): 191-198. DOI: *https://doi.org/10.52403/ijrr.20250523*

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