



Innovative 21st-century teaching: effectiveness of pbl in enhancing 4c skills on genetic diversity

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ARTICLE INFO	ABSTRACT
<p>Article history Received: 23 January 2025 Revised: 24 March 2025 Accepted: 27 March 2025</p> <p>Keywords: 4C Skills 21st Century Problem Based Learning</p>	<p>Developing 4C skills (critical thinking, creativity, communication, and collaboration) is crucial for students' success, yet many Indonesian students still struggle to master these competencies. This study evaluates the impact of PBL on 10th-grade students' 4C skills in the genetic diversity topic at SMAN 3 Jember. Using a quasi-experimental design, 72 students were divided into control (36) and experimental (36) groups. Pre- and post-tests assessed critical and creative thinking, while communication and collaboration were observed directly. Data were analyzed with ANCOVA and Kruskal-Wallis tests in IBM SPSS Statistics 24. The findings revealed significant improvement in the experimental group, moving from "poor" to "critical, creative, communicative, and collaborative," The control group showed only "modest" progress to "fair." In conclusion, PBL is an effective approach to enhancing students' 4C skills, offering a valuable model for innovative teaching aligned with 21st-century education goals.</p>

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INTRODUCTION

Education is a planned effort that supports learning conditions and the learning process. Thus, education is defined as a conscious endeavor leveraging communication between knowledgeable individuals and their students to transfer information, develop skills, and contribute to a more structured life in the future. Moreover, course design and academic motivation influence the learning process and outcomes, emphasizing the importance of planning in education to support students' skill development. (Li & Zhu, 2023; Rahman et al., 2022). Education in the 21st century is closely linked to possessing 4C skills: critical thinking, creativity, communication, and collaboration. With these 4C skills, the focus of education must be reformed to enhance students' learning outcomes, preparing them for future life challenges (Kurniawan, 2020). However, in Indonesia's current educational system, students lack well-developed 4C skills (Widodo & Warnadani, 2020). This is evident in students' low collaboration skills within groups, inadequate public speaking abilities, limited critical thinking abilities, and insufficient creativity in learning (Suparya et al., 2022). In today's digital age, the ability to think critically and creatively is a vital skill for students to navigate global challenges. These skills are not only essential in academics but also have a profound impact on both professional and personal life (Nurfaizah et al., 2022; Siswati & Hariyadi, 2024).

As time progresses, technological advancements supported by digitization in education drive efforts to improve human resource quality (Timotheou et al., 2023). On the other hand, 21st-century education emphasizes creativity, critical thinking, collaboration, and communication skills, posing challenges for teachers to develop innovative teaching methods (Herlinawati et al., 2024). Traditional learning, which focuses solely on memorization, needs to be transformed to enhance students' cognitive abilities and higher-order thinking skills (Devi et al., 2023).

The rapid development of the education system requires teaching models to align with educational objectives (Albina et al., 2022). One of the recommended models in the independent curriculum is Problem-Based Learning (PBL), which is grounded in real-life issues, fostering problem formulation, problem identification related to prior knowledge, and the presentation of solutions (Yusup & Salsabila, 2023). The problem-solving process in learning requires thinking, analyzing, evaluating, and generating ideas (Sari et al., 2021).

Problem-Based Learning (PBL) is a model used in teaching, where teachers present problems related to students' real-life experiences with the expectation that it helps them better understand the learning material (Rehman et al., 2024). Problem-Based Learning (PBL) equips students with the ability to independently construct concepts based on real-life problems through investigative skills, making it one of the most advanced learning models (Liu & Pásztor, 2022). This approach enhances students' engagement in learning, fosters effective collaboration with peers, and strengthens interactions with teachers, creating a more conducive classroom environment. In PBL, the teacher acts as a facilitator, while students take center stage in the learning process (Pattiasina & Sopacua, 2022).

In this model, problems are introduced at the start of the learning process, with students expected to solve or provide solutions to these problems by the end of the session (Hastawan et al., 2024; Nofziarni et al., 2020). PBL is also defined as a learning model with stages that train and develop problem-solving skills derived from students' real-life experiences, thereby enhancing higher-order thinking skills (Widyastuti & Airlanda, 2020). The Problem-Based Learning model is characterized by a learning approach that focuses on solving real-world problems by students, with the teacher acting as a facilitator (Sarnoko et al., 2024). Implementing this model encourages students to take a more active role in the learning process, enhancing their understanding, constructing concepts from acquired knowledge, and developing their skills (Jannah & Saifuddin, 2024).

The Problem-Based Learning (PBL) model is particularly effective in teaching genetic diversity in biology, as it allows students to actively engage with real-world issues such as biodiversity conservation, genetic variations in populations, and the impact of environmental changes on genetic traits (Maryuningsih et al., 2022). By exploring case studies on endangered species, selective breeding, or genetic disorders, students can analyze data, formulate hypotheses, and collaborate to find solutions. This approach enhances their critical thinking, problem-solving, and analytical skills, while also deepening their understanding of how genetic diversity influences species survival and adaptation (Blancia & Fetalvero, 2021).

According to (Perdana et al., 2020), research findings indicate an improvement in critical thinking skills through the application of learning stages based on problem analysis. The PBL model is student-

centered, fostering critical thinking and collaboration (Darmuki et al., 2022), enabling students to express scientific opinions and relate them to their learning outcomes. (Palupi et al., 2020) assert that PBL can enhance and develop students' knowledge, enabling self-evaluation in both learning processes and outcomes. This study presents a novelty by comprehensively analyzing how the Problem-Based Learning (PBL) model not only enhances critical thinking and collaboration skills but also fosters students' creativity and communication while assessing the effectiveness of their scientific opinion expression on learning outcomes through a more in-depth evaluation method.

The PBL model is often accompanied by learning media such as instructional videos. Using videos as a teaching medium aims to make students more interested and motivated to solve problems by combining audio and visual elements (Wulandari & Nana, 2021). Aim to investigate the impact of the Problem-Based Learning model on students' 4C skills in high school biology education, specifically on genetic biodiversity in grade 10 (Papilaya & J. Tuapattinaya, 2022).

METHODS

Research Design

The type of research applied is quantitative research, which involves measurement, calculation, formulas, processes, hypothesis formulation, data collection techniques, data analysis, and drawing conclusions (Waruwu, 2022). The research method used is a quasi-experimental design (Naz et al., 2023). This method is also referred to as a pseudo-experiment, where the researcher involves two classes: one control class and one experimental class, subjected to treatment through the implementation of the problem-based learning model (Abraham & Supriyati, 2022). The selection of classes is not random but is conducted by performing a homogeneity test and administering a preliminary test on the population. The quasi-experimental design used is the pretest-posttest. The following is the design of this research method:

Table 1

Research Design for Class Treatment with a Quasi-Experimental Design

Group	Pre-test	Treatment	Post-test
Control Class	O1	X1	O2
Experiment Class	O1	X2	O2

Table 1 shows the grouping of the research into experimental and control classes, where both classes underwent a pre-test (O1) before the treatment and a post-test (O2) after the treatment. The conventional model utilized a lecture method and workbook exercises (X1), while the problem-based learning model was assisted by instructional videos and the provision of student worksheets (LKPD) (X2).

Population and Samples

The research population consists of two classes with 72 students from grade X of SMA Negeri 3 Jember during the odd semester of the 2024/2025 academic year. These 72 students belong to the Science (MIPA) program, with each class consisting of 36 students. The sampling technique involves conducting a preliminary test on the population to obtain the research sample (control-experimental classes). Based on the average preliminary test scores, statistical analysis will be carried out using IBM SPSS Statistics 24, including Kolmogorov-Smirnov normality tests, Levene's hypothesis tests, and Anova equivalence tests. The research sample was determined as 36 students from class X.1 as the experimental group and 36 students from class X.2 as the control group.

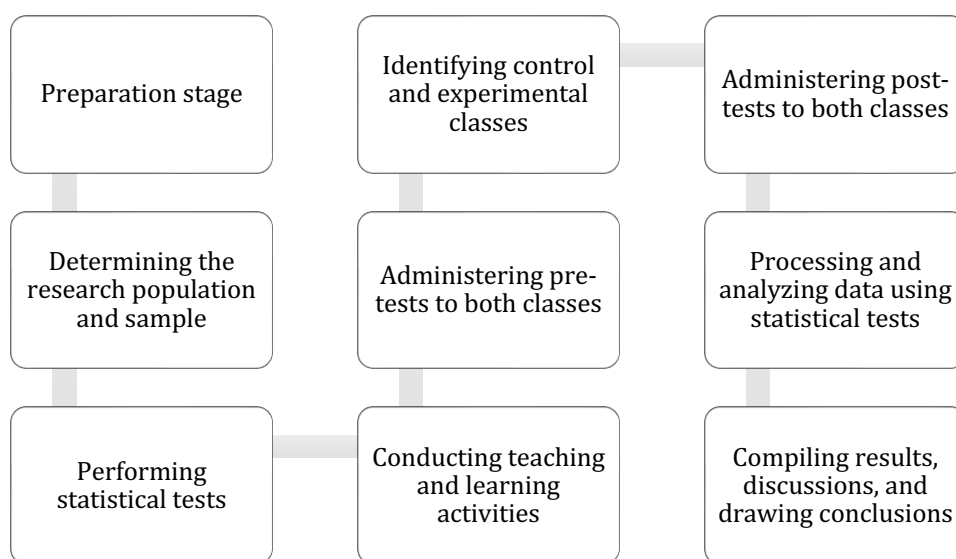
Instrument

The data collection instrument used was a test instrument. The test instrument used in this study has undergone a validity test by a validator, who confirmed that the instrument is suitable for use. Tests were conducted through pre-test and post-test questions given to students to assess their critical thinking and creative skills. The pre-test and post-test questions consisted of five short essay items, each designed based on indicators of critical and creative thinking skills. Another instrument used was an assessment rubric to evaluate communication and collaboration skills. This assessment was conducted by observers directly during group discussions and the presentation of discussion results. The research instruments were validated by two experts. The test instrument used in this study has undergone a

validity test by a validator, who confirmed that the instrument is suitable for use with an average score above 95. The overall validation results showed that the instruments were suitable for use in the study.

Procedure

The research procedure consisted of two main stages: the preparation stage and the implementation stage. Preparation stage, which included designing the research, conducting a literature review, and developing the research tools and instruments. Implementation stage, this involved determining the research population and sample, performing statistical tests, identifying control and experimental classes, administering pre-tests to both classes, conducting teaching and learning activities by providing treatments to the experimental class using a PBL (Problem-Based Learning) model assisted by instructional videos, while the control class followed a conventional Direct Learning model with worksheet (LKS) exercises. Students were divided into small groups for the experimental class to work on LKPD worksheets, while the control class used the biology textbooks for grade X. Post-tests were then administered to both classes, and data was processed and analyzed using statistical tests and assessment criteria. The process concluded with compiling results, discussions, and drawing conclusions. The following is a flowchart of the research procedure.



Flowchart 1. Research procedure

Data Analysis Techniques

The research data analysis technique employed hypothesis testing, including Anacova covariance analysis for critical and creative thinking skills, and the Kruskal-Wallis test for communication and collaboration skills. These were preceded by Kolmogorov-Smirnov normality tests and Levene's hypothesis tests using IBM SPSS Statistics 24. The 4C skills were categorized into several categories based on Bustami et al. (2023) and Purnamawati (2021).

RESULTS AND DISCUSSION

The normality test for critical and creative thinking skills using the Kolmogorov-Smirnov test and the data homogeneity test using Levene's Test were conducted before hypothesis testing. The normality test results indicated that the research data were normally distributed, and the homogeneity test showed that the data obtained were homogeneous. Subsequently, the Anacova covariance hypothesis test was performed, as presented in Table 4.

The Ancova test results for pre-test and post-test scores (Table 2) show a significance value of 0.000, which is < 0.05 . This finding aligns with previous studies by (Perdana et al., 2020), and (Darmuki et al., 2022), which also reported significant improvements in students' critical thinking and collaboration skills after implementing the PBL model. Therefore, it can be concluded that there is a significant effect of using the Problem-Based Learning (PBL) model on students' critical thinking and creative thinking skills.

Table 2
Anacova Test Results for Pre-test and Post-test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5133.427 ^a	2	2566.713	11.420	.000	.249
Intercept	32220.512	1	32220.512	143.354	.000	.675
Pretest	1960.038	1	1960.038	8.721	.004	.112
Kelas	3157.605	1	3157.605	14.049	.000	.169
Error	15508.573	69	224.762			
Total	267044.000	72				
Corrected Total	20642.000	71				

a. R Squared = .249 (Adjusted R Squared = .227)

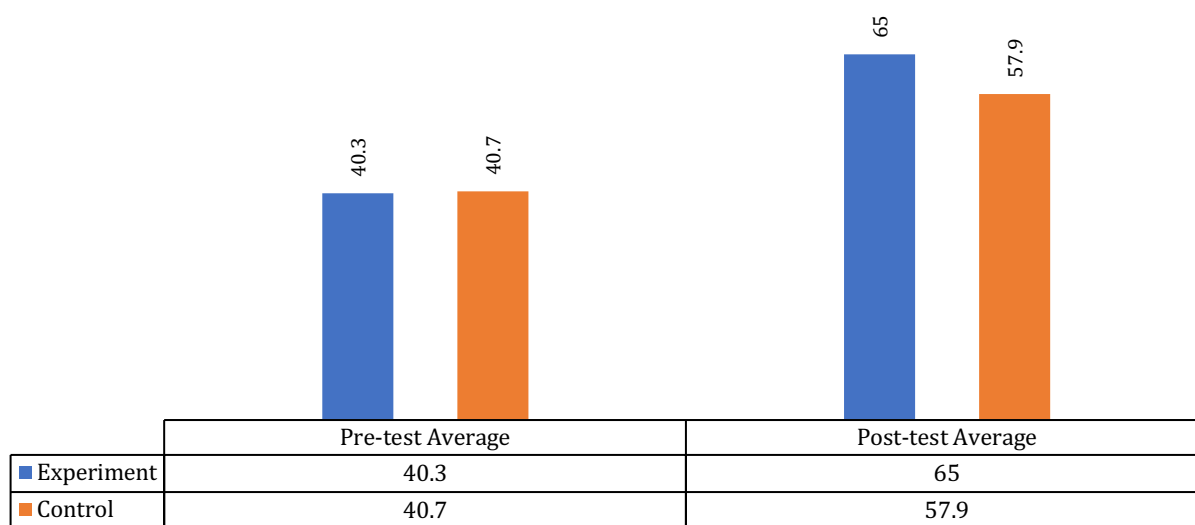


Figure 1. Average Pre-test and Post-test Scores

Figure 1 showed that the average pre-test scores of both classes are nearly equivalent, indicating that both classes had almost the same level of critical thinking skills, based on Table 2, categorized as less critical. After the treatment and the post-test, the experimental class experienced a higher increase, falling into the critical category, while the control class was categorized as moderately critical. Therefore, both classes demonstrated an improvement in critical thinking skills. Furthermore, (Palupi et al., 2020) found that PBL enhances students' ability to self-evaluate their learning processes and outcomes. The significant improvement in the experimental class supports these studies, confirming that PBL effectively enhances critical thinking skills compared to conventional learning methods.

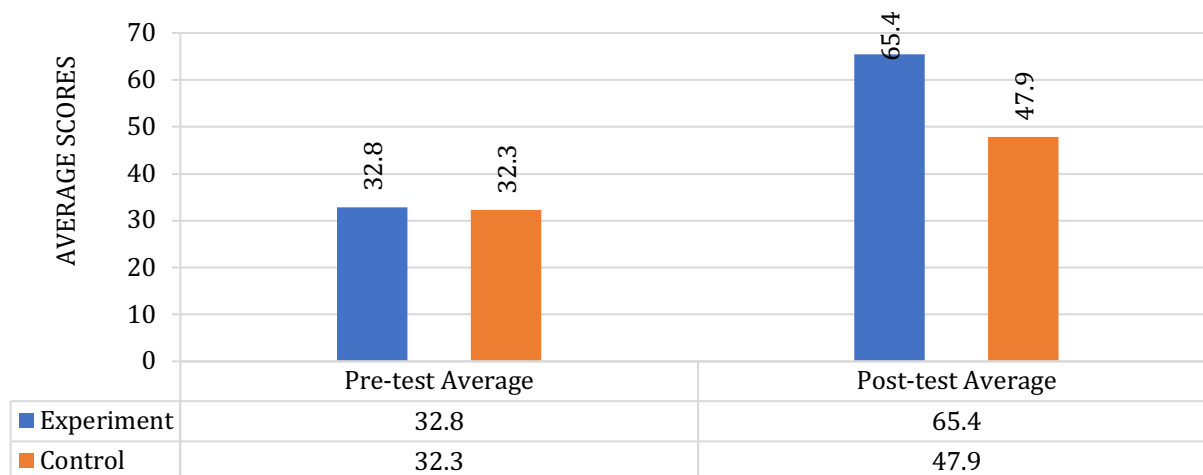


Figure 2. Average Pre-test and Post-test Scores

Figure 2 showed that the average pre-test scores of both classes are nearly equivalent, indicating that both classes had almost the same level of creative thinking skills, based on Table 2, categorized as less creative. After the treatment and the post-test, the experimental class experienced a higher increase, falling into the creative category, while the control class was categorized as moderately creative. Therefore, both classes demonstrated an improvement in creative thinking skills.

Table 3

Average Scores for Communication and Collaboration Skills

Class	Average	Criteria	Average	Criteria
Experiment	70	Communication	77,91	Collaboration
Control	58,75	Moderately communication	58,33	Moderately collaboration

Table 3 showed that the experimental class, based on Table 3, falls within the range of $61 \leq n \leq 80$, categorized as proficient in communication and collaboration. Meanwhile, the control class falls within the range of $41 \leq n \leq 60$, categorized as moderately proficient in communication and collaboration. Thus, the PBL model positively impacts students' communication and collaboration skills (Corebima et al., 2020).

Table 4

Kruskal-Wallis Test Results for Communication Skills

	Communication
Chi-Square	28.671
df	1
Asymp. Sig.	.000
a. Kruskal Wallis Test	
b. Grouping Variable: Class	

Table 4 showed the communication skills assessment results, with an Asymp. Sig. value of 0.000, which is < 0.05 . This indicates a significant difference in the communication levels of the experimental class (X.1) and the control class (X.2) when using the PBL learning model. This finding aligns with studies highlighting the impact of PBL on students' communication skills (Kanan & Mardiani, 2022).

Table 5

Kruskal-Wallis Test Results for Collaboration Skills

	Colaboration
Chi-Square	23.916
df	1
Asymp. Sig.	.000
a. Kruskal Wallis Test	
b. Grouping Variable: Class	

Table 5 showed the collaboration skills assessment results, with an Asymp. Sig. value of 0.000, which is < 0.05 . This indicates a significant difference in the collaboration levels of the experimental class (X.1) and the control class (X.2) when using the PBL learning model. This finding aligns (E. Sari & Hafandi, 2022), who concluded that PBL is effective for developing 21st-century skills, including collaboration.

Based on the results of the research data analysis, it was found that the PBL model significantly influenced students' 4C skills in biodiversity material at the genetic level. This is evidenced by a significant difference between the implementation of the PBL-based learning model in the experimental class and the conventional Direct Learning model in the control class.

The hypothesis test results showed that the use of the Problem-Based Learning (PBL) model influenced students' critical thinking skills. This was demonstrated by the results of the Anacova analysis of pre-test and post-test scores, as shown in Table 2. The assessment of critical thinking skills in Figure 1 revealed that the average post-test scores in both classes were higher than their pre-test scores. Initially, both the experimental and control classes demonstrated equivalent critical thinking skills categorized as less critical. However, after treatment, differences emerged, indicating the influence of the learning model. The experimental class improved to the critical category, while the control class reached the moderately critical category.

This finding aligns with (Ratnawati et al., 2020) who stated that critical thinking skills can be enhanced using a problem-based learning model. Students exposed to PBL demonstrate higher critical thinking skills than those using direct learning, which focuses on teacher-centered explanations and exercises that limit deeper thinking. According to (Ayunda et al., 2023), PBL serves as an innovation for developing critical thinking by presenting real-world problems followed by a student-centered problem-solving process. Similarly, (Shafira & Suratsih, 2023) argued that problem-based learning triggers questions, requiring students to seek solutions to satisfy their curiosity, thus fostering critical thinking.

The PBL syntax is closely related to improving critical thinking skills. According to Samsudin et al., (2021) and Kusumawati et al., (2022), the first syntax, orientation to the problem introduces real-life problems that encourage students to think critically by analyzing issues, identifying causes, and finding solutions. Additionally, the fifth syntax, analyzing and evaluating the problem-solving process, emphasizes critical evaluation of discussion outcomes (Salim et al., 2024). Thus, implementing PBL in learning improves students' critical thinking skills.

The hypothesis test also revealed that the PBL model influenced students' creative thinking skills, as evidenced by the Anacova analysis of pre-test and post-test scores in Table 2. The assessment of creative thinking skills in Figure 2 showed that the average post-test scores in both classes improved from their pre-test scores. Initially, both classes demonstrated equivalent creative thinking skills categorized as less creative. However, after treatment, differences emerged, indicating the influence of the learning model. The experimental class improved to the creative category, while the control class reached the moderately creative category.

(Handayani & Koeswanti, 2021) found that the PBL model presents real-world problems, encouraging students to expand their knowledge beyond memorization. This approach drives students to think creatively to solve problems. Creative thinking helps students find solutions that are unique, unconventional, and innovative, pushing their cognitive boundaries (Febrianingsih, 2022).

Creative thinking skills are also linked to PBL syntax. According to (Diniyah, 2023), in the PBL stage of analyzing and evaluating the problem-solving process, students must develop solutions requiring fluency and flexibility—key indicators of creative thinking. Additionally, creative thinking can be fostered during the presentation of problem-solving outcomes, whether orally or in writing. Furthermore, the third syntax, guiding group investigations, involves students generating original ideas to solve problems, emphasizing creativity. Therefore, the PBL model supports the enhancement of students' creative thinking skills.

Students' communication skills were assessed through observer evaluations of e-LKPD activities, group discussions, and presentations. Based on the average communication skills scores in Table 3, the experimental class fell into the proficient communication category, while the control class was in the moderately proficient category. Observers assessed each student using five indicators. Observations showed that the experimental class scored an average of 3–4, indicating good to very good communication skills, while the control class scored an average of 2–3, falling into the less proficient to good categories. Thus, the experimental class outperformed the control class.

The Kruskal-Wallis test results in Table 4 indicate a significant difference in communication skills between the two classes. The application of PBL in the experimental class significantly improved communication skills compared to the control class. This finding aligns with studies highlighting the impact of PBL on students' communication skills. (Kamah & Mardiani, 2022) argued that PBL effectively enhances communication skills compared to conventional models like Discovery Learning. PBL facilitates cooperation and group discussions, assisting students struggling with learning. (Siswati & Suratno, 2024) also stated that both in face-to-face meetings and through digital platforms, group discussions provide students with opportunities to exchange understanding, give and receive feedback, and strengthen their scientific argumentation skills. (Iftitahurrahimah et al., 2020) stated that PBL increases students' attention and focus, improving their communication skills. Moreover, (Corebima et al., 2020) noted that PBL supports communication skill development, particularly during the fourth syntax, where students present and discuss solutions, fostering oral communication.

Students' collaboration skills were assessed similarly to communication skills. Based on Table 3, the experimental class fell into the proficient collaboration category, while the control class was in the moderately proficient category. Observations revealed that the experimental class scored an average of

3–4, indicating good to very good collaboration skills, while the control class scored 2–3, falling into less proficient to good categories. Again, the experimental class outperformed the control class.

The Kruskal-Wallis test results in Table 5 show a significant difference in collaboration skills between the two classes. The application of PBL in the experimental class significantly improved collaboration skills compared to the control class. This finding aligns with (E. Sari & Hafandi, 2022), who concluded that PBL is effective for developing 21st-century skills, including collaboration. (Aldian & Wahyudiati, 2023) noted that good collaboration involves students building healthy relationships and achieving learning objectives. (Wela et al., 2020) and (Nurwahidah et al., 2021) emphasized that collaboration enables students to exchange ideas and work together to generate innovative solutions.

Collaboration skills are also linked to PBL syntax. The second syntax, organizing students for learning, emphasizes role-sharing and joint task planning within groups. (Elisabet et al., 2024) found that effective teamwork leads to optimal problem-solving outcomes. The fifth syntax, analyzing and evaluating the problem-solving process, encourages students to provide mutual feedback, which can drive group improvement (Wardani, 2023). Thus, implementing PBL enhances students' collaboration skills.

CONCLUSION

Concluded that the PBL model significantly influences students' 4C skills in biodiversity material at the genetic level. This is evidenced by the results of the Anacova test for critical and creative thinking skills. Additionally, the Kruskal-Wallis test results for communication and collaboration skills. Future research should explore variations by integrating other innovative media that can support problem-based learning (PBL), aiming to further enhance students' 4C skills.

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