Bioscientist: Jurnal Ilmiah Biologi
https://e-journal.undikma.ac.id/index.php/bioscientist

September 2026 Vol. 14, No. 3
e-ISSN: 2654-4571
pp. 1143-1155

The Effect of Collaborative Project-Based Learning on Students' Communication Skills at SMP Negeri 4 Palu

[1]Dwi Ninik Sunarti, [2*]Mursito S. Bialangi, [3]Masrianih, [4]Lestari M.P. Alibasyah, [5]Raya Agni, [6]Astija

[1,2,3,4,6]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Tadulako, Palu, Indonesia.

[5]Department of Science Education, Faculty of Teacher Training and Education, Universitas Tadulako, Palu, Indonesia.

*Corresponding Author e-mail: mursitobiologi@yahoo.co.id

Received: June 2026; Revised: July 2026; Accepted: August 2026; Published: September 2026

Abstract: This study aimed to analyze the effect of collaborative project-based learning (PjBL) on students' communication skills at SMP Negeri 4 Palu. A quasi-experimental nonequivalent control group design was employed, involving 22 students in the experimental group and 24 students in the control group selected through cluster random sampling. The intervention was implemented through a contextual project, the Eco-Soil Poster Campaign, which involved creating a digital poster campaign promoting soil health conservation within the school environment. Data were collected using a posttest communication skills questionnaire, while a cognitive pretest was administered to verify the initial equivalence of the two groups. The instrument was validated using Aiken's V and Cronbach's Alpha. The results revealed a significant difference between the two groups ($p = 0.018 < 0.05$), with the experimental group achieving a higher mean score (75.64%, categorized as Good) than the control group (69.83%, categorized as Fair), accompanied by a moderate effect size (Cohen's $d = 0.724$). These findings indicate that collaborative PjBL significantly improves students' communication skills and can be recommended as an effective instructional strategy for junior high school biology learning.

Keywords: Eco-soil poster campaign; communication skills; quasi-experimental design; PjBL

How to Cite: Sunarti, D. N., Bialangi, M. S., Masrianih, Alibasyah, L. M., Agni, R., & Astija. (2026). The Effect of Collaborative Project-Based Learning on Students' Communication Skills at SMP Negeri 4 Palu. *Bioscientist: Jurnal Ilmiah Biologi*, *14*(3), 1143–1155. https://doi.org/10.33394/bioscientist.v14i3.20867

https://doi.org/10.33394/bioscientist.v14i3.20867

INTRODUCTION

Communication skills are recognized as one of the essential competencies of the 21st century, alongside critical thinking, collaboration, and creativity (Partnership for 21st Century Learning, 2019). In science education, particularly biology learning, communication is not merely a complementary skill but an essential component of scientific practice. Scientific learning requires students to interpret evidence, construct explanations, engage in argumentation, and communicate scientific ideas effectively (National Research Council [NRC], 2012). Therefore, the development of communication skills is crucial for enabling students to participate actively in scientific discussions and collaborative knowledge construction. According to Sholeh et al. (2021), communication skills in collaborative learning consist of four key indicators: the ability to systematically express opinions, synthesize information from various sources, provide clear instructions to group members, and motivate peers to actively participate in shared tasks.

Despite its importance, biology learning in many classrooms remains dominated by teacher-centered instructional approaches that provide limited opportunities for students to engage in meaningful communication activities. Traditional instructional approaches often emphasize the transmission of knowledge rather than active knowledge construction, thereby reducing opportunities for students to discuss, negotiate ideas, and communicate scientific reasoning (Hmelo-Silver, 2004; Prince, 2004). Damanik (2025) reported that the dominance of lecture-based instruction was associated with lower levels of students' communication skills. Similarly, Hadijah et al. (2023) found that many students experienced difficulties in organizing and expressing their thoughts during classroom presentations and group discussions. Comparable challenges have also been reported in different educational contexts, including Malaysia (Mahmud et al., 2020), Turkey (Kavlu, 2017), and the United States (Condliffe et al., 2017), suggesting that conventional instructional approaches may provide insufficient opportunities for students to develop academic communication competencies.

A similar situation was observed at SMP Negeri 4 Palu. Preliminary classroom observations conducted in June 2025 indicated that students showed limited participation in group discussions and classroom presentations during biology lessons. Interviews with biology teachers further revealed that students' communication skills had not been systematically assessed and had not yet become an explicit learning objective. These conditions highlight the need for instructional strategies that intentionally provide communication-rich learning experiences. Active learning approaches that engage students in collaborative inquiry and authentic problem-solving have been suggested as effective strategies for promoting communication and other higher-order skills (Freeman et al., 2014; Bell, 2010).

Project-Based Learning (PjBL) has been widely recognized as an instructional approach that promotes active learning, collaboration, problem-solving, and higher-order thinking skills (Krajcik & Shin, 2014; Kokotsaki et al., 2016). Through authentic projects, students are encouraged to investigate meaningful problems, exchange perspectives, make collaborative decisions, and communicate their ideas through tangible products (Larmer et al., 2015). However, several research gaps remain regarding the specific contribution of PjBL to students' communication skills. Previous studies have predominantly examined the effects of PjBL on academic achievement, conceptual understanding, and cognitive outcomes, whereas investigations focusing specifically on communication skills as the primary outcome remain relatively limited, particularly at the junior high school level (Hasni et al., 2016). Furthermore, many studies have emphasized statistical significance without evaluating the practical magnitude of intervention effects through effect size analysis, although effect size provides important information regarding the educational relevance of an intervention (Lakens, 2013). In addition, the implementation of collaborative PjBL within the context of *Soil and Sustainability of Life* learning at the junior high school level remains insufficiently explored.

This study addresses these gaps by implementing collaborative Project-Based Learning (PjBL), adapted from the six phases proposed by Thomas (2015), through an authentic environmental project entitled the **Eco-Soil Poster Campaign**. The project involves the development of digital posters promoting soil health conservation within the school environment, requiring students to conduct observations, discuss scientific issues, construct arguments, collaborate within groups, and present their products to authentic audiences. Authentic learning experiences that involve real-world contexts have been shown to enhance student engagement and facilitate meaningful knowledge construction (Herrington et al., 2014). The topic of *Soil and Sustainability of Life* was selected because it is closely connected to students' daily experiences and provides opportunities for scientific inquiry, discussion, argumentation, and communication of environmental messages. The novelty of this study lies in the integration of four aspects that remain insufficiently explored in previous research: (1)

the junior high school educational context, (2) soil-related biology content, (3) the Eco-Soil Poster Campaign as an authentic product addressing local environmental issues, and (4) the evaluation of practical intervention effects using Cohen's *d* effect size.

Theoretically, this study is grounded in Vygotsky's social constructivist theory, particularly the concept of the Zone of Proximal Development (ZPD), which emphasizes that students' cognitive and communicative development occurs optimally through guided social interactions (Vygotsky, 1978). Within collaborative learning environments, students develop understanding through dialogue, peer interaction, and shared problem-solving processes (Vygotsky, 1978; Johnson & Johnson, 2009). In the PjBL framework, this theoretical perspective is reflected through collaborative discussions, teacher scaffolding, peer interaction, and product presentations. These activities provide opportunities for students to negotiate meanings, exchange perspectives, provide feedback, and refine scientific explanations, thereby strengthening communication competencies (Vankerckhoven et al., 2023). Based on the identified problems and research gaps, this study aims to determine the effect of collaborative project-based learning on the communication skills of students at SMP Negeri 4 Palu. Specifically, this study investigates whether students who participate in collaborative PjBL demonstrate significantly higher communication skills than those who experience conventional biology instruction.

METHOD

Research Design

This study employed a quantitative approach using a quasi-experimental method. This approach was selected because the research was conducted in a real school setting, where complete control over all variables, as in a true experimental design, was not feasible. The study used a non-equivalent control group design, in which naturally existing classes (*intact classes*) were assigned as the experimental and control groups (Sugiyono, 2019). This design was selected because individual random assignment of students was not possible within the school context; therefore, comparisons were made between existing classes while maintaining comparable learning conditions.

The research design consisted of a pretest, treatment, and posttest for both groups, as presented in Table 1.

Table 1. Non-equivalent control group design

Class	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_1	–	O_2

Notes:
X = Collaborative project-based learning (PjBL)
O_1 = Preliminary cognitive ability test for verifying initial group equivalence
O_2 = Posttest communication skills questionnaire

Participants and Sampling Procedure

The study was conducted from 4–6 March 2026 at SMP Negeri 4 Palu, located at Jl. Gatot Subroto No. 6, East Palu District, Palu City, Central Sulawesi, Indonesia. The study population consisted of all eighth-grade students enrolled in the 2025/2026 academic year. The population included 320 students distributed across 10 parallel classes.

Sampling was conducted using cluster random sampling. Initially, all 10 classes were included in a random selection procedure to determine two sample classes. Subsequently, the assignment of the selected classes as the experimental and control groups was also determined through random selection. The final sample consisted of class VIII Sirsak ($n = 22$) as the experimental group and class VIII Apel ($n = 24$) as the control group. Because the sample size was relatively limited and the study was conducted in only one school, the findings should be interpreted cautiously and generalized primarily to educational contexts with similar characteristics.

Initial Equivalence Assessment

Before the intervention, both groups completed a pretest consisting of a cognitive ability assessment. The pretest was administered to examine the comparability of students' initial knowledge between groups and was not intended as a direct measurement of baseline communication skills.

The initial equivalence of communication-related characteristics was assumed based on the similarity of the selected classes obtained through the cluster random sampling procedure. The independent samples t-test results of the pretest scores showed no significant difference between the experimental and control groups ($t = 0.493$; $df = 44$; $p = 0.625 > 0.05$), indicating that both groups had comparable initial cognitive conditions before the intervention.

However, because communication skills were not measured through a pretest, differences in students' initial communication profiles could not be completely ruled out. This aspect is recognized as a limitation of the quasi-experimental design applied in this study.

Research Instrument

The primary instrument used in this study was a communication skills questionnaire developed based on the four indicators proposed by Sholeh et al. (2021). The questionnaire consisted of 40 statements measured using a five-point Likert scale ranging from 1 (Never) to 5 (Very Often). Each indicator was represented by 10 items. The communication skills indicators and item distribution are presented in Table 2.

Table 2. Blueprint of the communication skills questionnaire

No.	Indicator	Number of Items	Item Numbers
1	Expressing opinions	10	1–10
2	Summarizing information	10	11–20
3	Providing instructions	10	21–30
4	Motivating group members	10	31–40

Instrument validity was assessed by three expert validators using Aiken's V coefficient. The validation analysis produced an average V value of 0.787 ($V \geq 0.75$), indicating that the instrument met the validity criteria (Retnawati, 2016). Reliability testing using Cronbach's alpha resulted in a coefficient of $\alpha = 0.94$, demonstrating very high internal consistency (Field, 2018).

Although the main instrument was a self-report questionnaire, observational records during project presentations were also collected as supporting evidence to strengthen the interpretation of students' communication performance. These observational records were used descriptively and were not included in the inferential statistical analysis.

Ethical Considerations

The research was conducted after obtaining permission from the school administration. Students participated in the learning activities as part of the regular instructional process, and students' identities and research data were kept confidential throughout the study.

Data Analysis

The collected data were analyzed using several statistical procedures. Prior to hypothesis testing, assumption tests were conducted, including the Shapiro–Wilk normality test and Levene's test for homogeneity of variance. Data were considered normally distributed and homogeneous when $p > 0.05$ (Field, 2018). The hypothesis was tested using an independent samples t-test at a significance level of $\alpha = 0.05$ (Pallant, 2020). The null hypothesis (H_0) was rejected when the Sig. (2-tailed) value was < 0.05.

In addition to statistical significance testing, the practical significance of the intervention was evaluated using Cohen's d effect size (Lakens, 2013). The effect size was interpreted as follows: $d < 0.5$ indicates a small effect, $0.5 \leq d < 0.8$ indicates a medium effect, and $d \geq 0.8$ indicates a large effect.

The categorization of students' communication skills achievement was based on the percentage score criteria adapted from Arikunto (2013), as presented in Table 3.

Table 3. Categorization of Students' Communication Skills Achievement

Percentage Score (%)	Category
81–100	Very Good
61–80	Good
41–60	Fair
21–40	Poor
0–20	Very Poor

RESULTS AND DISCUSSION

Before interpreting the effects of the intervention, verification of the initial equivalence between the two groups was an essential methodological requirement. An independent samples t-test conducted on the pretest data showed no significant difference between the experimental and control groups ($t = 0.493$; $df = 44$; $p = 0.625 > 0.05$). This finding indicates that both groups started from comparable baseline conditions prior to the intervention. This verification was not merely a procedural requirement; rather, it provided an important foundation for interpreting differences in posttest scores as being associated with the implemented learning intervention rather than inherent differences in students' initial abilities.

Establishing baseline equivalence is particularly important in quasi-experimental research. Unlike true experimental designs that rely on individual randomization to control confounding variables, the nonequivalent control group design employed in this study does not involve individual-level random assignment. Therefore, statistical confirmation of baseline equivalence before treatment serves as an essential mechanism for strengthening internal validity (Shek & Wu, 2018). Given that the initial equivalence between groups was statistically confirmed, the observed differences in posttest performance can be interpreted as being closely related to variations in the instructional approaches applied.

Descriptive Statistics

An overview of students' communication skills in both groups is presented in Table 4.

Table 4. Descriptive statistics of students' communication skills

Group	N	Mean	SD	Min	Max	Percentage (%)	Category
Experimental	22	151.27	15.98	112	176	75.64%	Good
Control	24	139.67	20.23	96	180	69.83%	Fair

Note: Percentages were calculated by converting raw scores relative to the maximum possible questionnaire score (200).

Table 4 shows that the experimental group achieved a mean raw score of 151.27 out of a maximum score of 200, equivalent to 75.64%, whereas the control group obtained a mean raw score of 139.67, equivalent to 69.83%. The difference in raw scores between the two groups (11.606 points) served as the basis for the t-test calculation, while the percentage values represent the proportional achievement relative to the maximum instrument score.

Results of Assumption Testing

Before conducting the main hypothesis testing, it was necessary to confirm that the data met the assumptions required for parametric statistical analysis. The results of the Shapiro–Wilk normality test and Levene's test for homogeneity of variance are summarized in Table 5.

Table 5. Results of statistical assumption tests

Test	Group	Statistic	df	Sig.	Conclusion
Shapiro–Wilk	Experimental	0.944	22	0.244	Normal
Shapiro–Wilk	Control	0.952	24	0.298	Normal
Levene's Test	–	1.584	1, 44	0.215	Homogeneous

The Shapiro–Wilk significance values for the experimental group ($p = 0.244$) and control group ($p = 0.298$) exceeded the $\alpha = 0.05$ threshold, indicating that the data distribution in both groups was normal. Furthermore, the Levene statistic value of 1.584 with $p = 0.215$ (>0.05) demonstrated that the variances between the two groups were homogeneous. Meeting both assumptions provided sufficient statistical justification for proceeding with the independent samples t-test using the equal variances assumed condition (Pallant, 2020).

Hypothesis Testing

The independent samples t-test resulted in a Sig. (2-tailed) value of 0.018 ($p < 0.05$), indicating that H_0 was rejected and H_1 was accepted. This result demonstrates that there was a significant difference in communication skills between students who participated in collaborative PjBL and those who received conventional instruction. The complete hypothesis testing results are presented in Table 6.

Table 6. Results of hypothesis testing

Variable	Assumption	t	df	Sig.	Mean Difference	SD Experimental	SD Control	SE
Communication Skills	Equal variances assumed	2.453	44	0.018	11.606	15.98	20.23	4.730

The experimental group obtained an average communication skill score of 75.64% (categorized as Good), whereas the control group achieved 69.83% (categorized as Fair). The mean difference of 11.606 raw score points indicates that the difference was not only statistically significant but also meaningful from a categorical perspective, as the two groups demonstrated different levels of communicative competence.

Indicator-Level Analysis

A deeper understanding of the differences between groups requires analysis beyond overall scores. Indicator-level analysis was conducted by converting the mean scores into percentages relative to the maximum score for each indicator (50). Comparisons of the four communication skill indicators between the experimental and control groups are presented in Figure 1 and Table 7.

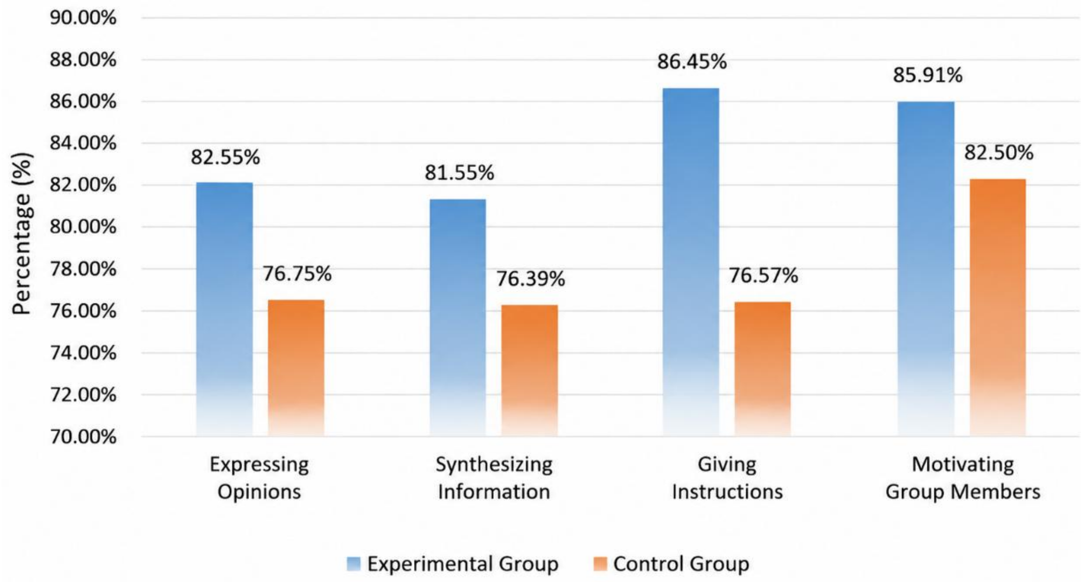

Figure 1. Average percentage scores for each communication skill indicator

Table 7. Comparison of achievement for each communication skill indicator

Indicator	Experimental		Control		Difference
	Percentage	SD	Percentage	SD	
Expressing opinions	82.55%	7.66	76.75%	10.02	5.80%
Summarizing information	81.55%	8.12	76.39%	9.67	5.16%
Giving instructions	86.45%	7.82	76.57%	10.89	9.88%
Motivating group members	85.91%	7.45	82.50%	9.81	3.41%

The indicator of giving instructions showed the largest difference between groups (9.88%), with the experimental group achieving 86.45% compared with 76.57% in the control group. The indicators of expressing opinions and summarizing information also demonstrated higher achievement in the experimental group, with differences of 5.80% and 5.16%, respectively. Meanwhile, motivating group members showed the smallest difference between groups (3.41%).

Effect Size

Although statistical significance provides evidence of differences between groups, effect size analysis is necessary to determine the practical magnitude of the impact of collaborative PjBL. The calculation of Cohen’s d is presented in Table 8.

Table 8. Effect size calculation results

Variable	Cohen's d	Category
Communication Skills	0.724	Medium

The Cohen's d value of 0.724 falls within the medium effect category based on the criterion of $0.5 \le d < 0.8$ (Lakens, 2013). This finding indicates that collaborative PjBL was not only statistically significant but also produced a measurable positive impact on the development of students' communication skills at the junior high school level.

The findings of this study indicate that students who participated in collaborative PjBL demonstrated higher communication skills than those who experienced conventional instruction, with differences that were statistically significant and practically meaningful. This finding supports previous research indicating that PjBL can promote active engagement, collaboration, and the development of higher-order competencies through student-centered learning processes (Krajcik & Shin, 2014; Kokotsaki et al., 2016). PjBL provides students with opportunities to investigate authentic problems, exchange ideas, construct solutions collaboratively, and communicate their understanding through meaningful products (Bell, 2010; Larmer et al., 2015). More specifically, Lee et al. (2024) demonstrated that collaborative project-based learning significantly improved communication competencies among nursing students, suggesting that the benefits of PjBL extend across different educational contexts.

The effectiveness of the intervention in the present study may also be attributed to the characteristics of the *Soil and Sustainability of Life* topic, which is concrete, contextual, and closely related to students' daily experiences. Contextual science learning allows students to connect theoretical concepts with real-world phenomena, thereby encouraging meaningful discussion, scientific reasoning, and communication of ideas (National Research Council [NRC], 2012). Furthermore, authentic learning environments have been shown to enhance student engagement by providing opportunities for learners to apply knowledge in realistic situations and communicate their understanding to meaningful audiences (Herrington et al., 2014). In the Indonesian educational context, Palangi et al. (2025) also reported the effectiveness of PjBL in enhancing 21st-century skills within biology education settings in Palu.

The indicator-level analysis revealed that PjBL did not influence all dimensions of communication skills equally; rather, each communication component appeared to develop through different learning mechanisms. This pattern can be explained through the six phases of PjBL adapted from Thomas (2015), which emphasize inquiry, planning, collaboration, product development, presentation, and reflection. During the *start with the essential question* and project planning phases, students were required to express, negotiate, and systematically discuss ideas within their groups. Such collaborative interactions provide opportunities for students to articulate their thoughts, evaluate different perspectives, and construct shared understanding (Johnson & Johnson, 2009; Vygotsky, 1978). These activities directly facilitated the development of students' abilities to express opinions and synthesize information.

During the project implementation phase, particularly when students distributed responsibilities and coordinated group activities, the ability to provide clear instructions was intensively practiced. Collaborative learning requires students to communicate roles, clarify expectations, and regulate group processes, which may explain why the indicator of giving instructions demonstrated the largest difference between the experimental and control groups. Previous studies have emphasized that structured collaboration within project activities promotes interpersonal communication because students must continuously coordinate actions to achieve shared goals (Slavin, 2014).

During the presentation and evaluation phases, students were required to justify and communicate their products to an audience, thereby further strengthening their abilities to express opinions and synthesize information. Presenting scientific products to authentic audiences is an important component of PjBL because it requires students to organize information, select relevant evidence, and communicate ideas clearly (Krajcik & Shin, 2014; Larmer et al., 2015). Meanwhile, the indicator of motivating group members demonstrated the smallest difference between groups. This finding may be explained by the nature of motivational communication, which is influenced not only by instructional structures but also by interpersonal relationships, individual personality characteristics, and students' broader social interactions beyond the classroom context (Johnson & Johnson, 2009).

This pattern reinforces the argument proposed by Sholeh et al. (2021) that collaborative learning systematically develops multiple dimensions of communication skills through authentic learning activities. Almulla (2020) further emphasized that active involvement in project activities serves as an important predictor of communication development because communication functions as a practical tool for completing meaningful tasks. Similarly, Larmer et al. (2015) highlighted that when students create products intended for authentic audiences, such as environmental conservation campaign posters, they are encouraged to communicate effectively to ensure that their scientific messages are understandable and meaningful. These findings are also consistent with the broader evidence that active learning approaches enhance student performance and engagement compared with traditional instructional approaches (Freeman et al., 2014).

The medium effect size indicated by Cohen's *d* (0.724) suggests that collaborative PjBL provided a meaningful practical contribution to improving students' communication skills, although the effect did not reach the large-effect category. Several factors may explain why the magnitude of the effect remained moderate. First, the relatively short intervention period, which consisted of only three instructional meetings, may not have been sufficient to fully develop all dimensions of communication competence. PjBL requires repeated cycles of inquiry, collaboration, reflection, and product revision for students to gradually internalize these competencies (Holubova, 2018; Krajcik & Shin, 2014). Therefore, longer implementation periods may produce stronger and more stable effects.

Second, the relatively small sample size may have limited the precision of the effect size estimation. Small samples generally produce greater uncertainty in estimating intervention effects and may reduce the statistical stability of findings (Cohen, 1988). Third, students in the experimental group may not have been fully accustomed to the collaborative and productive demands of PjBL, meaning that the full potential of the model may not have been realized within a single project cycle. Previous research suggests that students often require adaptation time when transitioning from teacher-centered learning environments to student-driven collaborative approaches (Kokotsaki et al., 2016).

The practical significance of these findings is theoretically supported by Vygotsky's social constructivist perspective, particularly the concept of the Zone of Proximal Development (ZPD), which emphasizes that learning occurs through guided interaction and social mediation (Vygotsky, 1978). Transformative learning occurs when students negotiate scientific meanings and construct understanding through intensive verbal interactions with others (Vankerckhoven et al., 2023). Within project-based science learning environments, communication among students serves not only as a means of expressing knowledge but also as a mechanism for constructing new understanding through collaboration and shared problem-solving (Baran & Maskan, 2018).

In contrast, the performance of students in the control group reflects the limitations of conventional learning approaches in providing sufficient opportunities for expressive communication. Teacher-centered instruction often provides fewer structured opportunities for students to engage in extended dialogue, argumentation, and collaborative meaning-making (Prince, 2004). Students who are less confident or less active may receive fewer opportunities to develop their communication skills, whereas more expressive students may continue to dominate classroom interactions (Sani, 2022). Therefore, collaborative PjBL has the potential to provide broader opportunities for students to participate actively in communication processes. Nevertheless, the extent to which participation is distributed equally among individual students requires further investigation using more comprehensive research designs.

Although the findings are consistent with previous literature, several alternative explanations should be considered before drawing strong conclusions. First, baseline equivalence was verified only through cognitive pretest scores, whereas students' initial communication skills were not specifically measured before the intervention. Therefore, it remains possible that the experimental group possessed more favorable initial communication characteristics. Future studies should consider implementing communication skill pretests to strengthen internal validity.

Second, students experiencing PjBL for the first time may demonstrate positive responses partly due to the *novelty effect*, referring to increased enthusiasm toward a new instructional approach rather than the intrinsic effectiveness of the model itself. Third, teacher facilitation during project implementation and naturally occurring group dynamics may have influenced the outcomes independently of the instructional model. Fourth, variations in students' learning motivation between classes may have acted as uncontrolled confounding variables within the quasi-experimental design.

Several limitations should be acknowledged when interpreting these findings. The questionnaire-based instrument may have introduced potential self-report bias because students may have perceived themselves as more communicative after participating in PjBL due to positive learning experiences rather than substantial changes in actual communication performance. Self-report measures are known to be vulnerable to response bias and social desirability effects, particularly when assessing personal competencies and perceptions (Podsakoff et al., 2003). Therefore, future research should combine self-report instruments with direct observations, performance assessments, or communication rubrics to obtain more comprehensive evidence.

Furthermore, the generalizability of the findings is limited because the study was conducted in a single school with specific socioeconomic and geographical characteristics. Therefore, caution is required when extending these findings to different educational contexts. Finally, the quasi-experimental design limits the strength of causal interpretations. Although baseline equivalence was statistically confirmed, not all potential confounding variables could be fully controlled without individual-level randomization.

CONCLUSION

This study indicates that collaborative project-based learning (PjBL) is associated with significantly higher communication skills among junior high school students learning the topic of *Soil and Sustainability of Life* at SMP Negeri 4 Palu ($p = 0.018$).

Students who participated in the collaborative PjBL intervention achieved a higher mean communication skill score (75.64%, categorized as Good) than those who received conventional instruction (69.83%, categorized as Fair), with a moderate effect size (Cohen's d = 0.724). These findings suggest that the integration of authentic, collaborative project activities, such as the Eco-Soil Poster Campaign, provides meaningful opportunities for students to practice expressing ideas, organizing information, giving instructions, and engaging with peers during biology learning.

However, the interpretation of these findings should be limited to the specific context of the study, including the sample characteristics, learning materials, and intervention duration. Given the quasi-experimental design and the absence of a communication skill pretest, further studies are needed to confirm the consistency of these effects across different educational settings. Nevertheless, collaborative PjBL represents a promising instructional approach for supporting the development of communication skills in junior high school biology education.

RECOMMENDATION

For junior high school biology teachers, the implementation of collaborative PjBL may be optimized through several practical considerations: (1) using communication skill rubrics as assessment guidelines throughout the project process; (2) assigning rotating group roles to ensure that each student has opportunities to practice communication skills; (3) requiring each group to present their project products to the class; and (4) conducting brief reflections on the communication process after project completion.

For future researchers, it is recommended to employ a pretest–posttest design that specifically measures communication skills rather than relying solely on cognitive assessments. Direct observations of students' communication behaviors should also be incorporated to strengthen the validity of the findings. Further replication studies with longer intervention periods and more diverse samples are needed to examine the generalizability of these findings across different educational contexts.

ACKNOWLEDGMENT

The authors would like to express their gratitude to Universitas Tadulako, particularly the Biology Education Study Program, Faculty of Teacher Training and Education, for providing the facilities and opportunities to conduct this research. The authors also sincerely thank all eighth-grade students of SMP Negeri 4 Palu for their enthusiastic participation in this study, as well as the school authorities for granting permission and providing full support during the data collection process.

REFERENCES

Almulla, M. A. (2020). The effectiveness of the project-based learning (PBL) approach as a way to engage students in learning. *SAGE Open, 10*(3), 1–15. https://doi.org/10.1177/2158244020938702

Arikunto, S. (2013). *Prosedur penelitian: Suatu pendekatan praktik*. Rineka Cipta.

Baran, M., & Maskan, A. (2018). The effect of project-based learning on pre-service physics teachers' electrostatics achievement and attitude. *Kalem Eğitim ve İnsan Bilimleri Dergisi, 8*(1), 97–113.

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Condliffe, B., Quint, J., Visher, M. G., Bangser, M., Drohojowska, S., Saco, L., & Nelson, E. (2017). *Project-based learning: A literature review*. MDRC.

Damanik, O. Y. (2025). *Pengaruh model Project-Based Learning terhadap keterampilan komunikasi siswa SMA Negeri 2 Muaro Jambi* [Undergraduate thesis, Universitas Jambi].

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (5th ed.). SAGE Publications.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Hadijah, R., Wulandari, S., & Fitriana, H. (2023). Pengaruh model pembelajaran berbasis proyek terhadap kemampuan komunikasi siswa. *Jurnal Pendidikan Sains, 7*(1), 45–56.

Hasni, A., Bousadra, F., Belletête, V., Benabdallah, A., Nicole, M. C., & Dumais, N. (2016). Trends in research on project-based science and technology teaching and learning at K–12 levels: A systematic review. *Studies in Science Education, 52*(2), 199–231. https://doi.org/10.1080/03057267.2016.1226573

Herrington, J., Reeves, T. C., & Oliver, R. (2014). *Authentic learning environments*. Springer.

Holubova, R. (2018). Effective teaching methods: Project-based learning in physics. *Universal Journal of Educational Research, 6*(3), 506–512. https://doi.org/10.13189/ujer.2018.060312

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*, 235–266.

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*(5), 365–379. https://doi.org/10.3102/0013189X09339057

Kavlu, A. (2017). The impact of project-based learning (PjBL) on undergraduate EFL students' critical thinking and collaboration skills. *Journal of Education in Black Sea Region, 3*(1), 3–16.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 275–297). Cambridge University Press.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for *t*-tests and ANOVAs. *Frontiers in Psychology, 4*, Article 863. https://doi.org/10.3389/fpsyg.2013.00863

Larmer, J., Mergendoller, J. R., & Boss, S. (2015). *Setting the standard for project based learning: A proven approach to rigorous classroom instruction*. ASCD.

Lee, M., Moon, J. Y., Park, H. R., Kim, M., & Lee, Y. M. (2024). The effectiveness of a collaborative project-based learning program on nursing students' problem-solving, communication, and self-directed learning competencies. *BMC Nursing, 23*, Article 21. https://doi.org/10.1186/s12912-024-01682-4

Mahmud, M. M., Thuseethan, S., & Rajasingham, L. (2020). Collaborative project-based learning and communication skills among secondary school students in Malaysia. *International Journal of Emerging Technologies in Learning, 15*(14), 45–58. https://doi.org/10.3991/ijet.v15i14.14587

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Palangi, J., Jamhari, M., Agni, R., Laenggeng, A. H., Fardha, R., & Febriawan, A. (2025). Pengaruh model project based learning berbasis STEM terhadap keterampilan berpikir kreatif dan motivasi belajar peserta didik pada mata pelajaran biologi di SMAN 4 Palu. *Bioscientist: Jurnal Ilmiah Biologi, 13*(3), 1950–1960.

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS* (7th ed.). Open University Press.

Partnership for 21st Century Learning. (2019). *Framework for 21st century learning*. Battelle for Kids.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88*(5), 879–903.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231.

Retnawati, H. (2016). *Analisis kuantitatif instrumen penelitian*. Parama Publishing.

Sani, R. A. (2022). *Pembelajaran berbasis HOTS (Higher Order Thinking Skills)*. Tira Smart.

Shek, D. T. L., & Wu, F. K. Y. (2018). The role of pretest and baseline equivalence in quasi-experimental studies. *Journal of Experimental Education, 86*(4), 1–15.

Sholeh, M., Joyoatmojo, S., & Sunardi. (2021). Collaborative learning as an effort to develop students' communication skills. *International Journal of Multicultural and Multireligious Understanding, 8*(2), 194–202. https://doi.org/10.18415/ijmmu.v8i2.2375

Slavin, R. E. (2014). Cooperative learning and academic achievement: Why does groupwork work? *Anales de Psicología, 30*(3), 785–791.

Sugiyono, S. (2019). *Metode penelitian pendidikan: Pendekatan kuantitatif, kualitatif, dan R&D*. Alfabeta.

Thomas, J. W. (2015). *A review of research on project-based learning*. The Autodesk Foundation.

Vankerckhoven, H., Kyndt, E., & Vandenberghe, R. (2023). The role of collaborative learning in developing students' communication competences: A systematic review. *Educational Research Review, 39*, Article 100528. https://doi.org/10.1016/j.edurev.2023.100528

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.