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Enhancing Collaborative Problem-Solving Skills through a Multimodal Project-Based Pedagogical Model

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a b s t r a c t

Background: Collaborative Problem Solving (CPS) is recognized as an essential 21st-century competency; however, elementary school students often demonstrate limited ability to solve problems collaboratively due to the lack of learning experiences that integrate cognitive, social, and communicative skills.

Aim: This study aimed to examine the effectiveness of a multimodal Project-Based Learning (PjBL) model in enhancing CPS skills among fifth-grade elementary school students.

Methods: A quantitative approach with a quasi-experimental nonequivalent control group design was employed involving 57 fifth-grade students, consisting of 28 students in the experimental group and 29 students in the control group. Data were collected through observation and performance assessments based on the OECD Collaborative Problem Solving framework and analyzed using descriptive and inferential statistics.

Results: The findings revealed that students who participated in the multimodal PjBL model achieved significantly higher CPS skills than those in the control group. The experimental group's mean score increased from 37.74 to 89.21, whereas the control group improved from 38.09 to 66.81. A significant difference was found between the groups in Post-test performance ($p < .001$). The experimental group also outperformed the control group across key CPS dimensions, including problem understanding, idea development, collaboration, innovation, and communication of solutions. Integrating multimodal learning experiences into project-based learning effectively promotes the development of CPS skills in elementary education.

Conclusion: This study contributes empirical evidence supporting multimodal PjBL as an innovative pedagogical model capable of simultaneously strengthening cognitive and social competencies required for 21st-century learning.

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1. Introduction

The development of the 21st century demands a fundamental transformation in the education system, from mere mastery of content to the development of higher-order thinking skills and social skills (Ceballos et al., 2026; Dayanti et al., 2025; Haqqi et al., 2025). One key

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competency that has received global attention is Collaborative Problem Solving (CPS), namely the ability of individuals to work together effectively to understand and solve complex problems (Andrews-Todd & Forsyth, 2023; Rojas et al., 2021). OECD (2017) emphasizes that CPS is an integration of cognitive (problem-solving) and social (collaboration) abilities that are essential in modern life and the workplace.

The urgency of developing Collaborative Problem-Solving skills is strongly supported by international evidence. The PISA 2017 assessment, which directly measures CPS, reported generally low levels of students' collaborative and problem-solving abilities, particularly in developing countries including Indonesia (OECD, 2017). This pattern is consistent with subsequent PISA results, which show that Indonesian students continue to perform below the OECD average in reading, mathematics, and science literacy, indicating limited higher-order thinking skills (OECD, 2018, 2023). These findings align with prior research emphasizing that weak performance in complex tasks is associated with insufficient development of collaborative and metacognitive skills essential for 21st-century learning (Griffin & Care, 2015; Voogt & Pareja Roblin, 2023). Moreover, studies indicate that conventional instructional practices in many developing education systems provide limited opportunities for students to engage in authentic collaboration and inquiry-based problem solving (Andrews-Todd & Forsyth, 2023; Mattessich, P. W., & Johnson, 2018). Accordingly, there is a clear need for innovative pedagogical models that integrate cognitive, social, and collaborative learning dimensions to address persistent CPS skill gaps.

In the context of elementary education, particularly in Natural and Social Sciences, CPS is highly relevant due to its contextual, phenomenon-based material characteristics, and its demand for active student involvement in understanding real-world problems (da Silva et al., 2025). However, various studies show that learning practices in elementary schools are still dominated by a teacher-centered approach, which limits student interaction, exploration, and collaboration (Gillies, 2023; Hsia et al., 2021; Huang et al., 2017). As a result, students are less trained in developing collaborative and collective problem-solving skills (Rojas et al., 2021).

One approach considered effective in addressing these challenges is Project-Based Learning (PjBL). This model emphasizes learning through authentic, collaborative, and problem-based projects (Alsmadi et al., 2024). Several studies have shown that PjBL can improve students' critical thinking skills, creativity, and problem-solving abilities (Ling et al., 2024; O'Toole et al., 2026; Xu et al., 2026). Furthermore, PjBL also provides space for students to interact intensively in groups, thus potentially developing collaborative aspects (Farshad & Fortin, 2026). However, most of these studies still examine learning outcomes partially, not specifically measuring Collaborative Problem Solving as an integrated construct as formulated by the OECD.

On the other hand, the development of modern learning theory emphasizes the importance of a multimodal approach, namely the use of various modes of representation such as visual, audio, kinesthetic, and digital in the learning process (Jewitt et al., 2016; Mayer, 2024a). This approach has been proven to increase student engagement, deepen conceptual understanding, and support the construction of more meaningful knowledge (Dunkin & Forgette, 2014; El-Saftawy et al., 2024). In the context of collaborative learning,

multimodality has the potential to enrich interactions between students through various means of communication and representation of ideas (Ding & Cha, 2024). However, research integrating a multimodal approach into the PjBL model to develop CPS is still very limited, especially at the elementary school level.

Based on the literature review, several significant research gaps remain, each rooted in identifiable limitations of prior work. PjBL research has consistently demonstrated benefits for critical thinking and individual problem-solving (Farshad & Fortin, 2026; Imbaquingo & Cárdenas, 2023; Retno et al., 2025), yet these studies operationalize outcomes through individual performance metrics, leaving the social-cognitive processes of collaborative problem-solving systematically unexamined. Multimodal learning research similarly demonstrates gains in individual comprehension (El-Saftawy et al., 2024; Mayer, 2024b; Xiang et al., 2026), The field has not, however, theorized how groups co-regulate and negotiate meaning across representational modes, a social affordance that Ainsworth (2006) identified as undertheorized and that Holloway & Gouthro (2020) did not address in their collaborative designs. Beyond these disciplinary limitations, the OECD (2017) collaborative problem-solving framework, which defines CPS as encompassing both cognitive competencies and social participatory roles, has been deployed primarily in large-scale, yet has rarely served as an explicit measurement basis in classroom-based intervention research, particularly at the primary school level (Care et al., 2018; Griffin & Care, 2015; Vanderwel, 2025). Furthermore, quasi-experimental studies testing the integrated effect of project-based learning and multimodal learning on CPS with rigorous pre-post measurement remain extremely rare (Dorji, 2018; Farshad & Fortin, 2026).

This study addresses these limitations by adopting the OECD (2017) CPS framework simultaneously as a conceptual architecture and a measurement instrument, situating the intervention within fifth-grade elementary science classrooms, a context that is underrepresented in CPS research (Griffin & Care, 2015; Voogt & Roblin, 2023), and employing a quasi-experimental design that enables causal inference regarding the model's impact on both cognitive and social dimensions of CPS (Care et al., 2018; Guo et al., 2020; Kokotsaki et al., 2016).

The novelty of this research lies in three main aspects. First, this study integrates Project-Based Learning and multimodal learning explicitly based on competency indicators in the OECD Collaborative Problem Solving (CPS) framework (OECD, 2017), which has not been done in previous studies. Second, the OECD CPS framework is used in an integrated manner as a basis for learning design as well as a psychometric-based measurement instrument, resulting in a more systematic conceptual and evaluative construct compared to previous studies that still define CPS generally or have not measured it in a standardized manner. Third, this study provides empirical evidence regarding the implementation of multimodal collaborative design in fifth-grade science learning in elementary schools in Indonesia, thus enriching the contextual evidence from the elementary education level which is still limited in the international CPS literature.

Based on the analysis, this study aims to test the effectiveness of the multimodal Project-Based Learning model in improving the collaborative problem-solving skills of fifth-grade elementary school students in science learning. Theoretically, the results of this study are

expected to enrich the understanding of CPS as a construct that can be taught and measured at the elementary education level, while explaining how structured multimodal representations function as collaborative tools in project-based learning. Practically, the results of this study are expected to be a reference for curriculum developers and policy makers in designing learning environments that systematically develop collaborative competencies needed in 21st-century education.

2. Methods

2.1 Research Design

This study employed a quantitative approach using a quasi-experimental design, specifically a nonequivalent control group design. This design was selected because the researcher was unable to fully randomize the assignment of subjects to groups; however, it still permitted rigorous empirical testing of the treatment effects through systematic comparisons between the experimental and control groups (Creswell & Creswell, 2018). The experimental group received treatment in the form of a Project-Based Learning model grounded in a multimodal approach, while the control group engaged in conventional learning. Both groups were administered Pre-tests prior to the intervention and Post-tests following its completion in order to measure changes in students' Collaborative Problem-Solving abilities.

2.2 Research Procedures

The research procedure was carried out in four stages over the period of September to November 2025. The first stage was preparation, encompassing the development of learning materials and research instruments, as well as the testing of instrument validity and reliability. The second stage was the implementation of the experiment, in which the experimental group received instruction through six structured meetings implementing the multimodal Project-Based Learning model, while the control group received conventional teacher-centered instruction covering identical science content throughout all six meetings. Meetings 1 and 2 constituted the project initiation phase, in which students were presented with an authentic science problem through multimodal stimuli and engaged in guided group discussion to formulate a shared problem definition and establish project goals. Meetings 3 and 4 constituted the project development phase, in which students conducted collaborative investigation, collected data, and constructed multimodal project outputs including written reports, diagrams, and oral presentation materials, with each member fulfilling a designated role. Meetings 5 and 6 constituted the project presentation and evaluation phase, in which groups presented their findings using multimodal formats, received structured peer and teacher feedback, and conducted group self-evaluation of both the product and the collaborative process. The third stage was outcome measurement, conducted through the administration of CPS Pre-tests and Post-tests as well as structured observations during the learning process. The fourth and final stage was data analysis and conclusion drawing.

2.3 Participants

The population of this study comprised all fifth-grade students enrolled in public elementary schools in Cileunyi, Bandung Regency, West Java, Indonesia. The sample was

determined using a purposive sampling technique, yielding a total of 57 students drawn from two intact classes across two different public elementary schools within the same sub-district. The researcher independently determined the assignment of classes to experimental and control conditions based on the following criteria: first, both classes were at the same grade level (Grade 5); second, both classes demonstrated comparable academic achievement profiles as indicated by their most recent semester report scores; third, both schools operated under equivalent institutional conditions in terms of accreditation status, available facilities, and curriculum implementation; and fourth, neither class had prior exposure to project-based or multimodal instructional approaches. Based on these criteria, the fifth-grade class at the first school, comprising 28 students, was designated as the experimental group and received instruction through the multimodal Project-Based Learning model, while the fifth-grade class at the second school, comprising 29 students, was designated as the control group and received conventional teacher-centered instruction. The selection of two separate schools, rather than two classes within a single school, was intended to minimize the risk of treatment contamination between groups. The study focused specifically on measuring students' Collaborative Problem-Solving abilities within the context of science learning at the fifth-grade level.

2.4 Data Collection

Data collection in this study employed two primary methods: structured observation and performance assessment (Creswell & Creswell, 2018). Structured observation was conducted to measure students' Collaborative Problem-Solving skills throughout the learning process, while performance assessment was administered to evaluate the quality of group work outcomes in completing assigned projects. The primary instrument was a CPS observation sheet developed in accordance with the (OECD, 2017) framework, comprising twelve indicators that represent the integration of four problem-solving competencies and three collaboration competencies, rated using a four-point scale (1-4). The four problem-solving competencies consist of Exploring and Understanding, Representing and Formulating, Planning and Executing, and Monitoring and Reflecting. The three collaboration competencies consist of Building and Maintaining Shared Understanding, Taking Appropriate Action to Solve Problems, and Establishing and Maintaining Team Organization. The twelve indicators derived from the intersection of these competencies were as follows: (1) explaining the problem in one's own words, representing the ability to explore and understand the problem within the shared understanding dimension; (2) identifying important information within the group, representing the ability to represent and formulate a shared problem definition; (3) agreeing on shared steps toward a solution, representing the ability to plan and execute within the shared understanding dimension; (4) checking the comprehension of group members, representing the ability to monitor and reflect on shared understanding; (5) posing questions relevant to the problem, representing the ability to explore and understand possible collaborative actions; (6) proposing ideas or solutions, representing the ability to represent and formulate appropriate actions for problem-solving; (7) implementing the agreed-upon solution, representing the ability to plan and execute the collaborative action; (8) monitoring the group's work progress, representing the ability to monitor and reflect on the outcomes of collaborative actions; (9) distributing tasks within the group, representing the ability to explore and understand team roles and organizational norms; (10) working in accordance with assigned roles, representing the ability

to represent and formulate team structure and role allocation; (11) maintaining cooperation and positive interaction, representing the ability to plan and execute role commitments while adhering to group norms; and (12) evaluating the group's work outcomes, representing the ability to monitor team dynamics and adapt group organization when necessary. In addition, a performance assessment rubric was employed to evaluate the quality of students' solutions, the degree of cooperative engagement, and the effectiveness of project result presentations (Ofem et al., 2024; Stiggins, 2017).

The validity of the instruments was established through expert judgment and subsequently analyzed using Aiken's V formula (Aiken, 1985). All twelve indicators were declared valid, each yielding a V coefficient of 0.80 or above ($V \geq 0.80$), consistent with the threshold recommended for content validity in educational research (Aiken, 1985). Reliability was assessed using Cronbach's Alpha (Taber, 2018), which yielded a coefficient of 0.87, indicating that the instrument possesses high internal consistency in accordance with established criteria.

2.5 Data Analysis

Data analysis techniques were conducted quantitatively using descriptive and inferential statistics. Descriptive analysis was used to describe the mean, standard deviation, and distribution of students' CPS scores. Furthermore, inferential analysis was conducted by first testing the normality and homogeneity of the data as a prerequisite for analysis. If the data met the assumptions of normality and homogeneity, an independent sample t-test was used to determine the differences between the experimental and control groups. However, if the data were not normally distributed or homogeneous, the non-parametric Mann-Whitney U test was used to analyze the differences between the groups. All data analysis was performed using statistical software, with a significance level of 0.05.

3. Results

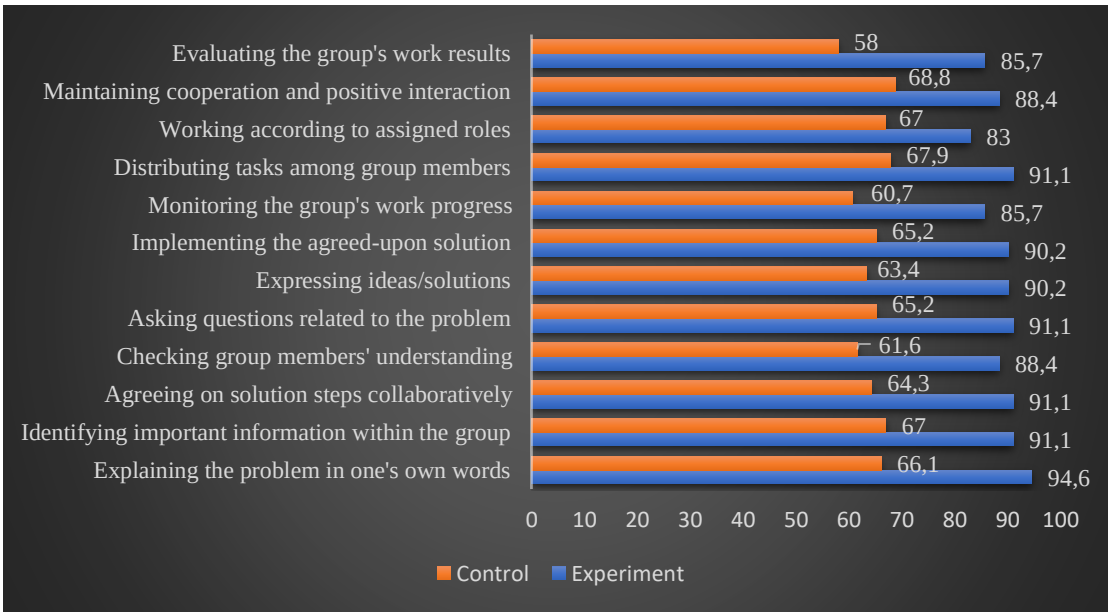
The descriptive statistics presented in Table 1 indicate that students who participated in the multimodal Project-Based Learning intervention demonstrated substantially greater improvements in both Creative Problem Solving and learning performance than those who received conventional instruction. Furthermore, the lower variability of Post-test scores in the experimental group suggests that the intervention produced more consistent learning outcomes across students. Overall, these descriptive patterns provide preliminary evidence that the intervention was associated with improvements in both higher-order problem-solving competence and overall learning performance. These observations were subsequently examined through inferential statistical analyses.

Table 1. Descriptive Statistics of CPS and Performance Scores

Variable	Group	N	Minimum	Maximum	Mean	Std. Deviation
CPS Pre-test	Experimental	28	25.00	50.00	37.74	9.55348
CPS Post-test	Experimental	28	77.10	97.90	89.21	6.79922
CPS Pre-test	Control	29	25.00	50.00	38.09	9.25675
CPS Post-test	Control	29	50.00	83.30	66.81	11.83380

Variable	Group	N	Minimum	Maximum	Mean	Std. Deviation
Performance Pre-test	Experimental	28	25.00	60.00	38.57	11.93013
Performance Post-test	Experimental	28	70.00	100.00	87.86	8.54493
Performance Pre-test	Control	29	25.00	50.00	38.97	9.57856
Performance Post-test	Control	29	50.00	80.00	63.45	11.10851

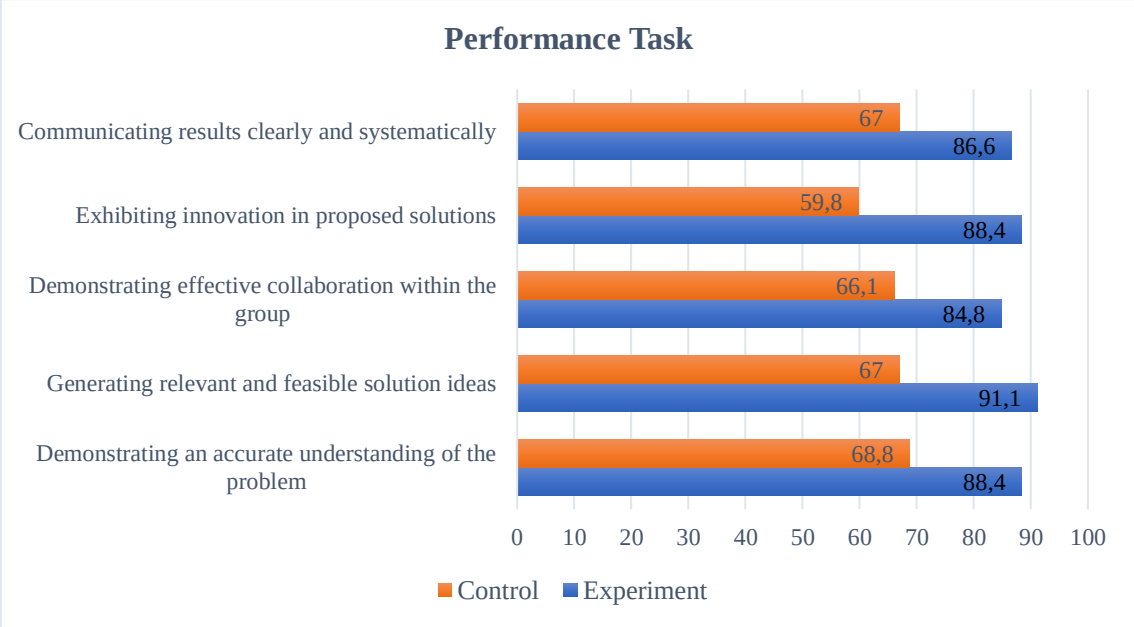
Graph 1. presents a comparison of the average scores between the experimental and control groups across various indicators of collaborative problem-solving skills. The diagram visualizes the performance differences between the two groups, allowing readers to clearly see the extent to which the intervention enhanced the experimental group's ability to understand problems, collaborate effectively, and generate as well as evaluate solutions.



Graph 1. Comparison of Average Scores Between Experimental and Control Groups Across Collaborative Problem-Solving Skill Indicators

As shown in Figure 1, the experimental group demonstrated consistently stronger performance than the control group across all collaborative problem-solving indicators. The largest differences were observed in indicators associated with higher-order cognitive and metacognitive processes, such as explaining problems in one's own words, evaluating group outcomes, monitoring collaborative progress, and reaching agreement on solution strategies. These findings suggest that the multimodal Project-Based Learning intervention enhanced students' ability to construct understanding, regulate collaborative learning, and engage in reflective evaluation during problem solving. Collectively, the descriptive patterns provide preliminary evidence that the intervention fostered balanced development of both the cognitive and collaborative dimensions of CPS, a finding that was subsequently examined through inferential statistical analyses.

Graph 2 shows the average scores of the experimental and control groups on five collaborative skill indicators, highlighting the experimental group's superior performance in problem understanding, idea generation, collaboration, innovation, and result communication.



Graph 2. Experimental and Control Group Scores on the Performance Task

Figure 2 demonstrates that the experimental group consistently outperformed the control group across all performance-task indicators. The greatest advantages were observed in indicators requiring creativity and higher-order thinking, particularly proposing innovative solutions, generating relevant and feasible solution ideas, and communicating results systematically. These patterns suggest that the multimodal Project-Based Learning intervention not only enhanced students' conceptual understanding of the problem but also strengthened their capacity to develop creative solutions and communicate their reasoning effectively. Overall, the descriptive findings indicate that the intervention promoted the integrated development of cognitive, creative, and collaborative competencies during authentic problem-solving activities.

Before conducting the group comparison, the distribution of the data was examined using the Shapiro-Wilk test. As presented in Table 2, the results indicated that several variables significantly departed from a normal distribution. In particular, the Post-test scores for Creative Problem Solving (CPS) and performance yielded p-values below the .05 significance threshold, indicating violations of the normality assumption. Since the data did not consistently satisfy the assumption of normality, subsequent between-group comparisons were conducted using the Mann–Whitney U test, which is appropriate for non-normally distributed data.

Table 2. Mann-Whitney U Test Results for CPS and Performance Scores

Variable	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)	Conclusion
CPS Pre-test	397.000	803.000	-0.145	0.885	Not significant
CPS Post-test	22.000	457.000	-6.149	<0.001	Significant

Performance Pre-test	389.000	795.000	-0.278	0.781	Not significant
Performance Post-test	36.000	471.000	-5.947	<0.001	Significant

Table 2 presents the results of the Mann–Whitney U test comparing the experimental and control groups on Creative Problem Solving and performance outcomes. No statistically significant differences were found between the two groups at the Pre-test stage for either CPS ($U = 397.00$, $Z = -0.145$, $p = .885$) or performance ($U = 389.00$, $Z = -0.278$, $p = .781$), indicating that the groups were comparable prior to the intervention. In contrast, statistically significant differences were observed at the post-test for both CPS ($U = 22.00$, $Z = -6.149$, $p < .001$) and performance ($U = 36.00$, $Z = -5.947$, $p < .001$). These results indicate that students who participated in the multimodal Project-Based Learning intervention achieved significantly higher levels of collaborative problem-solving and performance than those who received conventional instruction, suggesting that the intervention was effective in improving both learning outcomes.

4. Discussion

The results of this study indicate that the Project-Based Learning model based on a multimodal approach is significantly more effective in improving elementary school students' Collaborative Problem-Solving skills compared to conventional learning. The significant increase in scores in the experimental group, as well as the significant difference based on the Mann-Whitney U test, confirm that the intervention provided was able to have a real impact on the development of students' abilities. These findings also reinforce the view that 21st-century learning is not enough to focus only on content mastery, but must be able to integrate cognitive and social skills in a balanced manner (Ceballos et al., 2026; Dayanti et al., 2025; Jiang et al., 2026; Sukidin et al., 2026).

Conceptually, the improvement in CPS skills in the experimental group aligns with the framework proposed by the OECD (2017), which states that CPS is an integration of problem-solving and collaboration skills. The results of this study show that students not only improved in understanding and solving problems, but also in their ability to collaborate, communicate, and evaluate group work results. These findings support the views of Andrews-Todd & Forsyth (2023) and Rojas et al. (2021) that CPS develops optimally when individuals engage in meaningful social interactions. In other words, a learning process that positions students as active subjects in groups is key to developing thinking and social skills simultaneously (Rehman et al., 2024).

From a pedagogical perspective, the effectiveness of the PjBL model in this study can be explained by its key characteristics, which emphasize authentic problem-based learning and collaborative work. Students' involvement in real-life projects encourages them to identify problems, formulate solutions, and produce relevant products. This is evident from the high scores on indicators of problem understanding, idea development, and innovation in the experimental group. These findings align with previous research showing that PjBL can improve higher-order thinking skills, creativity, and problem-solving abilities (Ling et al., 2024; O'Toole et al., 2026; Xu et al., 2026). However, this study makes a further contribution by

demonstrating that when PjBL is designed in an integrated manner with structured collaborative activities, the impact is not only on individual cognitive aspects, but also on collaborative skills as part of CPS. This also addresses the limitations of previous research that tended to separate cognitive and social dimensions (Han et al., 2015; Song et al., 2025).

The role of the multimodal approach in this study is also a crucial factor in enhancing learning effectiveness. The use of various modes of representation, such as visual, audio, kinesthetics, and digital, provides students with the opportunity to understand concepts more deeply and express ideas in a more varied manner. This aligns with multimodal learning theory, which emphasizes that information presented through multiple channels is more easily understood and remembered (Jewitt et al., 2016; Mayer, 2024a). In the context of collaborative learning, multimodality also enriches interactions between students, as they can communicate and argue in various ways. The results of this study support the findings of Ding & Cha (2024) who stated that a multimodal approach can increase engagement and the quality of interactions in learning. Furthermore, this study provides a novel contribution by demonstrating that multimodality not only impacts individual learning but also strengthens social dynamics in group work, a finding rarely explored in previous research (El-Saftawy et al., 2024; Holloway & Gouthro, 2020).

When linked to a broader context, the findings of this study are relevant to the results of international studies such as PISA, which show that students' abilities in higher-order thinking and collaborative work are still low, particularly in developing countries (OECD, 2017, 2025). The low improvement in the control group in this study reflects the teacher-centred learning environment, which tends to limit student interaction and active participation (Gillies, 2023; Hsia et al., 2021; Huang et al., 2017). Conversely, the significant improvement in the experimental group indicates that implementing innovative, contextual, and student-centred learning models such as multimodal-based PjBL can be an effective solution to enhance collaboration skills (Shobirin et al., 2025).

From a methodological perspective, the quasi-experimental design enhances the credibility of the findings by allowing comparisons between groups with equivalent baseline characteristics. The absence of significant differences in the Pre-test scores indicates that the experimental and control groups began the study with comparable levels of collaborative problem-solving skills and performance, thereby strengthening the interpretation that the observed Post-test differences were associated with the multimodal Project-Based Learning intervention rather than pre-existing group differences (Creswell & Creswell, 2018). Beyond statistical significance, the findings also demonstrate meaningful educational value. The consistent improvements observed across both collaborative problem-solving and performance measures suggest that integrating multimodal learning into Project-Based Learning can effectively support students in analysing problems, generating and evaluating alternative solutions, collaborating with peers, and communicating ideas during authentic learning activities (Hsia et al., 2021; Johnson, D. W., & Johnson, 2018; Rice-Bailey & Chong, 2023). These competencies are fundamental to science learning and align with the broader educational goal of developing higher-order thinking and collaborative skills required for twenty-first-century learning.

5. Limitations

Although the findings of this study provide evidence of the effectiveness of multimodal Project-Based Learning (PBL) in improving elementary school students' collaborative problem-solving (CPS) skills, it has several limitations that should be acknowledged. First, the study involved participants from a limited geographic area and a relatively small sample size, which may limit the generalizability of the findings to different educational settings, grade levels, or sociocultural contexts. Consequently, caution is needed when extending these results beyond the population studied in this study.

Second, the intervention was implemented over a relatively short period of time. Although statistically significant improvements were observed, the study was not designed to determine whether these improvements are sustained over time or transferable to different learning contexts. Therefore, future longitudinal studies are needed to investigate the sustainability and transferability of collaborative problem-solving competencies after prolonged exposure to multimodal Project-Based Learning.

Third, the assessment of collaborative problem-solving primarily relied on observational measures and authentic performance tasks. Although the instruments demonstrated satisfactory validity and reliability, observational assessments necessarily involve professional judgment and may not fully capture the complexity of students' collaborative cognitive processes. Future research could strengthen the assessment framework by incorporating multiple sources of evidence, such as learning analytics, digital footprint data, peer assessments, reflective journals, think-aloud protocols, or video-based interaction analysis, to provide a more comprehensive understanding of students' collaborative learning processes.

Furthermore, this study focused primarily on learning outcomes and did not explicitly examine the mechanisms through which multimodal Project-Based Learning influences the development of collaborative problem-solving. Factors such as students' prior knowledge, self-regulated learning, motivation, group composition, the quality of peer interactions, teacher facilitation, and technology acceptance may also contribute to the intervention's effectiveness. Investigating these variables through a mixed-methods or exploratory research design would provide deeper insights into the processes underlying successful collaborative problem-solving.

6. Conclusion

This study demonstrates that multimodal Project-Based Learning (PjBL) is an effective instructional approach for enhancing elementary school students' collaborative problem-solving skills. The findings indicate improvements across both the cognitive and social dimensions of CPS, including problem understanding, solution generation, communication, collaboration, and reflective evaluation, thereby supporting the integrated competency framework proposed by the OECD (2017). These results suggest that combining authentic, problem-centered learning with multimodal forms of representation and interaction creates a more meaningful and engaging learning environment that promotes higher-order thinking and collaborative competence. From a practical perspective, the model offers an evidence-based strategy for addressing persistent challenges in elementary science education related to students' problem-solving and collaboration skills, while fostering competencies essential for twenty-first-century learning. The study therefore contributes to the literature by extending the theoretical understanding of

CPS as a multidimensional construct and by providing an empirically supported instructional model that can inform curriculum design and classroom practice in elementary education.

Author Contributions

Yusuf Tri Herlambang conceived the study, developed the research framework and pedagogical model, designed the research methodology, supervised the study, interpreted the findings, and prepared the original manuscript draft. Iim Siti Karimah contributed to the research design, coordinated the data collection process, conducted the literature review, and assisted in drafting and revising the manuscript. Yadi Suryadi contributed to the validation of the methodology, performed the data analysis, interpreted the results, and critically reviewed the manuscript for important intellectual content. Ardian Arief contributed to the validation of the research instruments, provided scholarly feedback on the pedagogical model, critically reviewed the manuscript, and contributed to the final revision. All authors contributed to the interpretation of the findings, approved the final version of the manuscript, and agreed to be accountable for all aspects of the work.

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