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Improving scientific literacy and collaboration skills through edugame-assisted problem-based learning

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Abstract. Primary school students continue to demonstrate low levels of scientific literacy and collaboration skills, highlighting the urgent need for innovative science instruction. This study investigated the effectiveness of Edugame-supported Problem-Based Learning (PBL) in enhancing fifth-grade students' scientific literacy and collaboration skills in learning the Solar System. The study employed a quantitative quasi-experimental pretest–posttest control group design. The population comprised all fifth-grade students at SDN 1 Jurangjero, Indonesia, and purposive sampling selected 60 students: 30 for the experimental group and 30 for the control group. Data were collected through testing, observation, questionnaires, and documentation using scientific literacy tests, collaboration observation sheets, and student questionnaires. The instruments demonstrated good validity (80%) and excellent reliability (Cronbach's alpha = .949). Data were analyzed using descriptive statistics and one-way multivariate analysis of variance (MANOVA) after meeting the assumptions of normality, homogeneity of variance, and homogeneity of covariance. Results revealed a significant multivariate effect of Edugame-supported PBL on both dependent variables ($Wilks'\ \Lambda = .089$, $F(2, 57) = 292.98$, $p < .001$). Edugame-supported PBL provides an effective instructional strategy for strengthening scientific literacy and collaboration skills while offering practical guidance for teachers and curriculum developers to implement interactive, student-centered science learning.

Introduction

Scientific literacy enables learners to interpret scientific information critically, evaluate evidence, and apply scientific knowledge to solve authentic problems, whereas collaboration skills foster effective communication, shared responsibility, and collective problem-solving in diverse learning environments (Grabau et al., 2021; Kelp et al., 2023; Wijaya et al., 2026). Contemporary educational frameworks increasingly recognize these competencies as prerequisites for developing higher-order thinking, teamwork, responsible citizenship, and lifelong learning in a rapidly evolving knowledge society (F. Chen & Chen, 2025; Loukomies & Palojoki, 2022). In line with Sustainable Development Goal 4 (Quality Education), UNESCO emphasizes that education should equip learners with the knowledge, skills, values, and attitudes needed to promote sustainable development and lifelong learning, while the Organisation for Economic Co-operation and Development (OECD), through the Programme for International Student Assessment (PISA), identifies scientific literacy and collaborative problem-solving as key indicators of educational quality and students' preparedness for future global challenges. Consequently, science education should move beyond transmitting factual knowledge by engaging students in inquiry, communication, and collaborative knowledge construction (Haatainen, 2022; Kati et al., 2023). Despite these international expectations, evidence from elementary school classrooms indicates that scientific literacy and collaboration skills have not yet developed optimally, revealing a persistent gap between educational policy and classroom practice and reinforcing the need for more innovative instructional approaches.

A preliminary classroom observation and interviews with fifth-grade teachers at SDN 1 Jurangjero identified several challenges in science learning, particularly in the Solar System topic. Observation records indicated that about 80% of students had difficulty explaining scientific concepts and relating them to everyday phenomena, reflecting limited scientific literacy. Moreover, 75% of students participated passively in group discussions, indicating weak collaboration skills, while 70% of classroom observations showed that science instruction remained predominantly teacher-centered, relying mainly on lectures and textbook-based explanations despite the availability of digital learning facilities. Collectively, these findings indicate that students struggle not only to understand scientific concepts but also to engage actively in collaborative learning. Previous empirical studies report similar findings, showing that teacher-centered science instruction limits students' participation, inquiry processes, and collaborative learning experiences (Asilevi et al., 2024). Conversely, inquiry-oriented and collaborative learning environments offer greater opportunities to develop scientific literacy, communication, and teamwork skills (Haatainen, 2022; Kati et al., 2023; Fazilla et al., 2026). Technology-enhanced collaborative learning has likewise been shown to strengthen students' communication, collaboration, and problem-solving abilities through meaningful learning experiences (Lei et al., 2024; Zhang et al., 2025).

Problem-Based Learning (PBL) has been widely recognized as a student-centered instructional approach that engages learners in solving authentic problems through inquiry, collaborative investigation, and reflective learning. Rooted in constructivist learning theory, PBL encourages students to actively construct knowledge by integrating prior understanding with new experiences, thereby promoting meaningful learning and conceptual development. Rather than receiving information passively, students are encouraged to identify problems, formulate explanations, evaluate evidence, and collaboratively communicate solutions. Numerous empirical studies have demonstrated that PBL effectively enhances students' higher-order thinking.

Numerous empirical studies have demonstrated that PBL effectively enhances students' higher-order thinking, conceptual understanding, and problem-solving abilities across various educational settings (Anazifa & Djukri, 2023; Čubela et al., 2023). Furthermore, engagement in authentic problem-solving has been shown to foster independent learning, critical reflection, and meaningful knowledge construction, making PBL an appropriate pedagogical approach for science education. Educational games facilitate meaningful knowledge construction through interactive visualization, immediate feedback, and authentic problem-solving activities. Previous empirical studies consistently report that game-based learning improves students' motivation, engagement, and academic performance by creating enjoyable, learner-centered learning experiences (Camacho-Sánchez et al., 2023; Dabbous et al., 2023). Meta-analytic evidence further shows that educational games positively affect academic achievement and learning engagement across diverse educational contexts (Tokac et al., 2023; Sailer et al., 2024). Moreover, digital game-based environments promote inquiry, communication, collaboration, and problem-solving, making them pedagogically compatible with the student-centered characteristics of Problem-Based Learning (Laakso et al., 2021; Pavloff-Pelkonen et al., 2025). However, although previous studies have independently demonstrated the effectiveness of Problem-Based Learning and educational games, empirical evidence integrating Edugame-supported Problem-Based Learning to simultaneously improve scientific literacy and collaboration skills among elementary school students, particularly in Solar System learning, remains limited.

Previous empirical studies have consistently demonstrated the educational benefits of Problem-Based Learning (PBL) and digital game-based learning when implemented independently. Problem-Based Learning has been widely recognized for promoting critical thinking, inquiry, and meaningful problem-solving, whereas educational games have been shown to enhance students' engagement, motivation, and interactive learning experiences across various educational contexts (Nadeem et al., 2023; Rayan et al., 2023). Emerging evidence also indicates that technology-supported collaborative learning environments contribute positively to students' communication, teamwork, and collaborative problem-solving skills (Sadegh-Zadeh et al., 2023; Marquez & Penman, 2023). However, most existing studies have examined these instructional approaches separately or have primarily focused on cognitive achievement, motivation, or engagement rather than simultaneously investigating scientific literacy and collaboration skills. Unlike previous studies, which generally evaluated the individual effectiveness of Problem-Based Learning or educational games, few investigations have explored their integrated implementation in elementary science education. Nevertheless, empirical evidence regarding the effectiveness of Edugame-supported Problem-Based Learning in simultaneously fostering scientific literacy and collaboration skills, particularly in Solar System learning at the elementary school level, remains scarce. This gap highlights the need for further empirical investigation to determine whether integrating Edugame-supported Problem-Based Learning can effectively address both competencies within a single instructional framework.

Previous empirical studies have predominantly examined Problem-Based Learning (PBL) and educational games as separate instructional approaches or have evaluated their effects on individual learning outcomes, such as academic achievement, motivation, engagement, or critical thinking (Čubela et al., 2023; Camacho-Sánchez et al., 2023; Tokac et al., 2023). Unlike previous studies, the present research integrates Edugame-supported Problem-Based Learning within a single instructional framework to simultaneously develop scientific literacy and collaboration skills, two essential competencies emphasized in contemporary elementary science education. Therefore, this study contributes to the literature by extending previous findings beyond cognitive and motivational outcomes and providing empirical evidence that integrating Edugame and Problem-Based Learning can simultaneously foster scientific literacy and collaboration skills in elementary science classrooms. Such evidence is expected to strengthen the theoretical and practical understanding of technology-supported, student-centered learning in primary science education.

Based on the identified research gap, the present study addresses two research questions: (1) Does Edugame-supported Problem-Based Learning significantly improve fifth-grade students' scientific literacy in Solar System learning? and (2) Does Edugame-supported Problem-Based Learning significantly improve their collaboration skills? Accordingly, two hypotheses were proposed: H1, Edugame-supported Problem-Based Learning significantly improves scientific literacy; and H2, Edugame-supported Problem-Based Learning significantly improves collaboration skills. Accordingly, this study aims to examine the effectiveness of Edugame-supported Problem-Based Learning in strengthening both competencies and provide empirical evidence supporting innovative, student-centered science instruction in elementary education.

Method

Research Design

This study used a quantitative approach with a quasi-experimental, non-equivalent pretest–posttest control group design. This design was selected because it enables researchers to examine the effects of an educational intervention in intact classroom settings where random assignment is not feasible (Denny et al., 2023). To investigate the effects of Edugame-assisted Problem-Based Learning (PBL) on students' scientific literacy and collaboration skills, the study employed an experimental group receiving PBL integrated with Edugame and a control group receiving instruction through the CTL conventional instruction approach. Table 1 presents the research design.

Table 1. Non-equivalent Pretest–Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	Y	O_4

Where:
O_1 and O_3 = Pretest
O_2 and O_4 = Posttest
X = Edugame-assisted Problem-Based Learning
Y = Contextual Teaching and Learning

Image 1 illustrates the research procedure used in this study. The diagram outlines the sequence of research activities, including participant selection, pretesting, treatment implementation, posttesting, and data analysis carried out throughout the study.

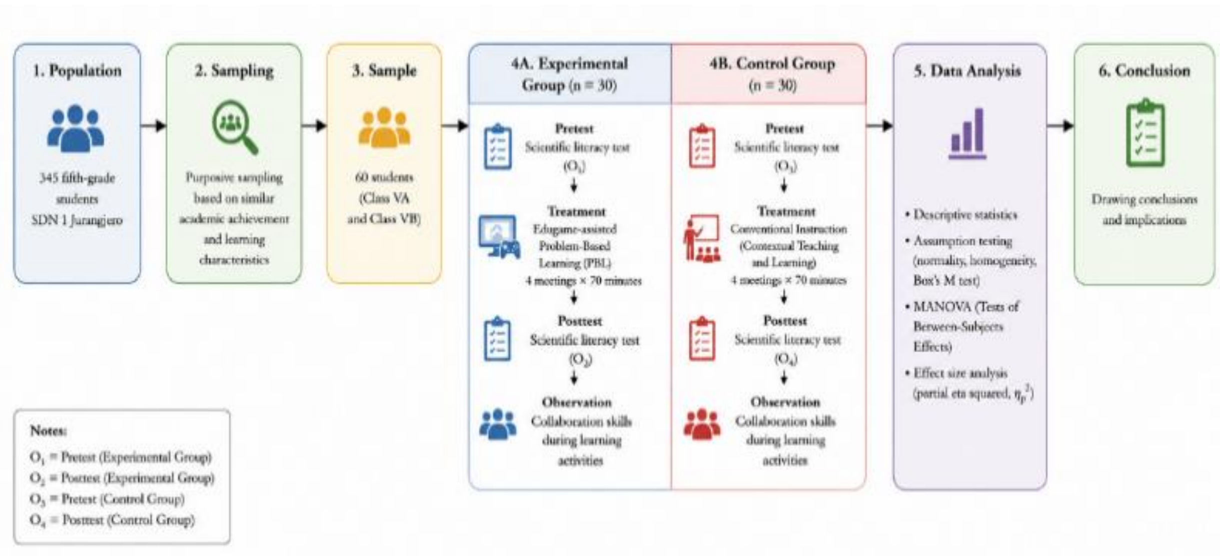

Image 1. Research Procedure Flowchart Source: Developed by the Authors based on (Creswell & Creswell, 2023) and (Buckler & Moore, 2023)

Research was conducted at SD Negeri 1 Jurangjero, Bogorejo District, Blora Regency, Central Java, Indonesia, from February to May 2026. A total of 345 students enrolled at the school constituted the target population. Using purposive sampling, 60 fifth-grade students with comparable academic achievement and learning characteristics were selected and assigned to two intact classes: Class VA (n = 30) as the experimental group and Class VB (n = 30) as the control group. Preliminary classroom observations revealed that many students experienced difficulties in scientific literacy and collaborative learning activities, particularly in learning the Solar System topic. Ethical approval for this study was granted by the Research Ethics Committee of Universitas PGRI Semarang

(Approval No. 124/KEPK/UPGRIS/II/2026). Permission to conduct the research was also obtained from the principal of SD Negeri 1 Jurangjero. The researchers obtained written informed consent from students' parents or legal guardians before data collection. Participation was voluntary, and all participant information was anonymized and treated confidentially throughout the study.

The research instruments included a scientific literacy test, a collaboration skills observation sheet, and a student response questionnaire. A scientific literacy test comprising 10 essay items was developed to assess students' ability to explain scientific phenomena, interpret scientific evidence, and apply scientific knowledge to authentic Solar System-related situations. A collaboration skills observation sheet was employed to evaluate students' communication, active participation, responsibility, and teamwork during classroom learning activities. A student response questionnaire was administered following the intervention to examine students' perceptions of the implementation of Edugame-supported Problem-Based Learning. Content validity of all instruments was established through expert judgment before data collection.

Scoring procedures followed standardized educational measurement principles to ensure consistency and objectivity in assessing students' performance (Creswell & Creswell, 2023; Revelle & Garner, 2024). Scientific literacy responses were evaluated using an analytic scoring rubric, with scores ranging from 0 to 4 for each essay item (0 = incorrect or no response; 1 = limited understanding; 2 = partially correct explanation; 3 = mostly correct explanation; and 4 = scientifically accurate and complete explanation). Maximum raw scores of 40 were subsequently converted to a 100-point scale for statistical analysis. Collaboration skills were assessed using a four-point Likert rating scale (1 = very poor, 2 = poor, 3 = good, and 4 = excellent) across the four observation indicators. Student responses to the questionnaire were likewise measured using a four-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree), with higher scores indicating more positive perceptions of the learning experience (Revelle, W., & Garner, 2024).

Scientific Literacy Test
Scientific literacy was measured using essay-based pretest and posttest instruments with 10 questions related to the Solar System. The questions assessed students' ability to explain scientific phenomena, interpret scientific evidence, and apply scientific concepts to real-life situations. The pretest was administered before treatment, while the posttest was administered after the intervention. instrumen dan soal soal.docx instrumen dan soal soal.docx
Table 2 presents the distribution of scientific literacy indicators.

Table 2. Blueprint of Scientific Literacy Instrument

Indicator	Item Numbers	Total Items
Explaining scientific phenomena	1, 2, 4, 5	4
Interpreting scientific evidence	3, 6, 7	3
Evaluating and applying scientific concepts	8, 9, 10	3
Total		10

Collaboration Skills Observation Sheet
Students' collaboration skills were assessed using an observation sheet consisting of 20 indicators observed during learning activities. The observation instrument measured students' participation, communication, responsibility, contribution to group tasks, and respect for peers' opinions.

Table 3. Blueprint of Collaboration Skills Observation Sheet

Aspect	Indicators	Number of Items
Participation	Active involvement in groups and discussions	1–4
Respect for Others	Listening and respecting opinions	5–8
Cooperation	Helping and working with peers	9–11
Responsibility	Completing assigned tasks	12–14
Problem Solving and Communication	Seeking information, discussing, presenting ideas	15–20
Total		20

Table 3 shows the distribution of 20 observation items across five aspects of collaboration skills. The instrument was designed to evaluate students' participation, respect for others, cooperation, responsibility, and problem-solving and communication skills during classroom learning activities.

Student Response Questionnaire

A questionnaire with twenty statements on a four-point Likert scale (Strongly Agree, Agree, Disagree, Strongly Disagree) was used to gather students' opinions about Edugame-assisted PBL. The questionnaire assessed students' interest, motivation, collaboration experiences, conceptual understanding, and overall satisfaction with the learning model (Sadegh-Zadeh et al., 2023).

Instrument Validation and Reliability

Before data collection, all research instruments, including the scientific literacy test and the collaboration skills observation sheet, underwent expert validation by specialists in elementary education and science education. Content validity was evaluated based on four aspects: content relevance, construction, language, and presentation, resulting in an average content validity coefficient of 0.80 (80%), indicating that the instruments were valid and suitable for implementation with minor revisions.

The researchers then examined instrument quality through a pilot study involving 30 fifth-grade students. Item validity was analyzed using the Pearson Product–Moment correlation coefficient, with item validity coefficients ranging from 0.462 to 0.841, all exceeding the critical value (rtable = 0.361, $\alpha = .05$), indicating that every test item was statistically valid. Internal consistency reliability was then evaluated using Cronbach's alpha, yielding a coefficient of .949, indicating excellent reliability and confirming that the instruments consistently measured the intended constructs (Heilala et al., 2023).

Treatment Procedure

Researchers conducted the intervention in four 70-minute sessions. The experimental group experienced Edugame-assisted Problem-Based Learning (PBL), while the control group was taught using conventional instructional approaches. Edugame functioned as an interactive digital learning medium that integrated educational games, scientific literacy activities, and collaborative problem-solving tasks related to the Solar System topic. The research followed four stages. Instrument development involved expert validation, revision, and pilot testing prior to implementation. Researchers subsequently administered a pretest to both groups to assess students' initial scientific literacy levels. The experimental group received Edugame-assisted Problem-Based Learning, while the control group was taught using conventional methods. Throughout the intervention, researchers observed students' collaboration skills and collected posttest and questionnaire data to evaluate the learning model's effectiveness (Sailer, Kiefer, et al., 2023).

Data Analysis

Data were analyzed using descriptive and inferential statistics. Descriptive statistics summarized students' scientific literacy and collaboration skills. Before conducting the inferential analysis, the assumptions of one-way Multivariate Analysis of Variance (MANOVA) were examined using the Shapiro–Wilk test to assess normality, Levene's test to evaluate the homogeneity of variances, and Box's M test to examine the equality of covariance matrices. After the assumptions were met, a one-way MANOVA was conducted to determine the multivariate effect of Edugame-supported Problem-Based Learning on students' scientific literacy and collaboration skills. Subsequently, the Tests of Between-Subjects Effects were conducted to examine the effect of the independent variable on each dependent variable individually. Effect sizes were estimated using partial eta squared (ηp^2) to determine the magnitude of the treatment effect. Following Cohen's (1988) guidelines, ηp^2 values of .01, .06, and .14 were interpreted as representing small, medium, and large effect sizes, respectively. All statistical analyses were performed using a significance level of $\alpha = .05$.

Descriptive Statistics

Descriptive statistics summarized students' scientific literacy and collaboration skills in both the experimental and control groups. The descriptive measures included the mean, standard deviation, minimum, and maximum for each dependent variable. These statistics provided an overview of students' performance before and after the intervention and served as the basis for subsequent inferential analyses.

Assumption Testing

Before conducting the one-way Multivariate Analysis of Variance (MANOVA), assumption tests were performed to assess whether the data were suitable for parametric analysis. Data normality was assessed using the Shapiro–Wilk test, while the homogeneity of variances was examined using Levene's Test. The equality of covariance matrices across groups was evaluated using Box's M Test. A significance value greater than 0.05 for the Shapiro–Wilk and Levene's tests indicated that the assumptions of normality and homogeneity of variances were met. For Box's M Test, a non-significant result ($p > 0.05$) indicated that the assumption of equality of covariance matrices was satisfied, allowing the MANOVA to be conducted.

Hypothesis testing was conducted using a one-way Multivariate Analysis of Variance (MANOVA) to examine the effect of Edugame-assisted Problem-Based Learning on students' scientific literacy and collaboration skills. We evaluated the multivariate effect using Wilks' Lambda. When a statistically significant multivariate effect was obtained, the Tests of Between-Subjects Effects were performed to determine the effect of the independent variable on each dependent variable individually. Statistical significance was established at the 0.05 level, with $p < 0.05$ indicating a significant effect..

Results and Discussion

Result Instrument

Results of instrument validity and reliability testing are presented first, followed by descriptive statistics of students' scientific literacy and teamwork abilities in accordance with the research objectives. Data suitability for one-way Multivariate Analysis of Variance (MANOVA) is then examined through assumption testing, including the Shapiro-Wilk test for normality, Levene's test for homogeneity of variances, and Box's M test for equality of covariance matrices. Subsequently, MANOVA results are presented, followed by the Tests of Between-Subjects Effects to examine the effect of Edugame-assisted Problem-Based Learning (PBL) on each dependent variable separately.

In this study, the experimental group was taught using Edugame-assisted Problem-Based Learning (PBL), whereas the control group received conventional instruction during Grade V IPAS on the Solar System topic. The intervention aimed to improve students' scientific literacy and collaboration skills by integrating problem-solving activities with digital educational games. Empirical findings indicate that this instructional approach effectively promotes both competencies. These findings are subsequently discussed by drawing on relevant theoretical frameworks and previous empirical studies to clarify the contribution of Edugame-assisted PBL to fostering essential twenty-first-century skills in elementary science learning.

Instrument Validity and Reliability

Before implementing the intervention, the researchers evaluated the instruments to ensure their validity and reliability in measuring students' scientific literacy and collaboration skills. Instrument validity was assessed using the Pearson Product–Moment correlation analysis, while internal consistency was examined using Cronbach's Alpha coefficient. The validity results indicated that all instrument items met the required criteria, with item-total correlation coefficients ranging from 0.379 to 0.879 ($p < 0.05$). The reliability analysis yielded a Cronbach's Alpha coefficient of 0.949, indicating excellent internal consistency. These findings demonstrate that the research instruments were valid and reliable for data collection. Table 4 presents the detailed results of the validity and reliability analyses.

Table 4. Reliability Test Results

Cronbach's Alpha	N of Items
.949	10

After confirming that the research instruments were valid and reliable, descriptive findings were examined to provide an initial overview of students' performance. Image 2 illustrates the comparison of the mean pretest and posttest scores for scientific literacy and collaboration skills in both the experimental and control groups.

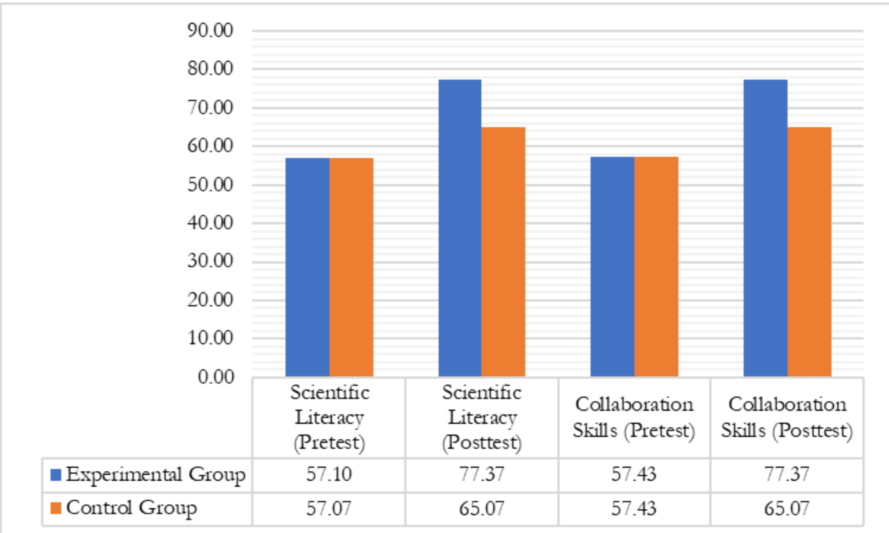

Image 2. Comparison of Mean Pretest and Posttest Scores for Scientific Literacy and Collaboration Skills Between the Experimental and Control Groups.

Descriptive Statistics

Descriptive statistics summarized students' scientific literacy and collaboration skills before and after the intervention. The analysis included the mean, median, mode, standard deviation, minimum, and maximum for each variable, providing an overview of the data's distribution and central tendency. Table 5 presents the complete descriptive statistics.

Table 5. Descriptive Statistics for Pretest and Posttest Scores of Scientific Literacy and Collaboration Skills

Statistics					
		Literacy_pre	Literacy_post	Collaboration_pre	Collaboration_post
N	Valid	60	60	60	60
	Missing	0	0	0	0
Mean		57.08	77.38	57.43	77.35
Median		57.00	76.50	57.00	77.00
Mode		55[a]	66[a]	58	69
Std. Deviation		3.381	8.525	2.473	8.647
Variance		11.434	72.681	6.114	74.774
Minimum		50	65	53	65
Maximum		65	91	63	91
Sum		3425	4643	3446	4641

a. Multiple modes exist. The smallest value is shown

Table 5 presents the descriptive statistics of students' scientific literacy and collaboration skills before and after the intervention. The mean scientific literacy score increased from 57.08 (pretest) to 77.38 (posttest), while the mean collaboration skills score increased from 57.43 to 77.35. Similar improvements were observed in the median scores, accompanied by higher minimum and maximum scores in the posttest. Overall, these descriptive results indicate improvements in both scientific literacy and collaboration skills following the implementation of Edugame-assisted Problem-Based Learning. Further inferential analyses were conducted to determine the statistical significance of these improvements

Assumption Tests

Prior to conducting the one-way Multivariate Analysis of Variance (MANOVA), the normality assumption was examined using the Shapiro–Wilk test. The results indicated that all significance values exceeded 0.05, demonstrating that the data for both scientific literacy and collaboration skills were normally distributed. Therefore, the normality assumption was met, and the data were appropriate for subsequent parametric analyses. The complete results of the Shapiro–Wilk test are presented in Table 6.

Table 6. Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Literacy	Experiment	.121	30	.200*	.963	30	.376
	Control	.107	30	.200*	.964	30	.382
Collaboration	Experiment	.109	30	.200*	.977	30	.743
	Control	.106	30	.200*	.971	30	.567

*. This is a lower bound of the true significance

a. Lilliefors Significance Correction

As presented in Table 6, the Shapiro–Wilk test indicated that all significance values exceeded 0.05, demonstrating that the posttest data for scientific literacy and collaboration skills in both the experimental and control groups were normally distributed. Therefore, the normality assumption required for MANOVA was satisfied.

Improvement of Students' Scientific Literacy

Students' scientific literacy significantly improved once Problem-Based Learning (PBL) was implemented with Edugame's help. Table 7 compares the pretest and posttest results for the experimental and control groups.

Table 7. Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	.999	26006.843[b]	2.000	57.000	<.001	.999	52013.687	1.000
	Wilks' Lambda	.001	26006.843[b]	2.000	57.000	<.001	.999	52013.687	1.000
	Hotelling's Trace	912.521	26006.843[b]	2.000	57.000	<.001	.999	52013.687	1.000
	Roy's Largest Root	912.521	26006.843[b]	2.000	57.000	<.001	.999	52013.687	1.000
Group	Pillai's Trace	.911	292.980[b]	2.000	57.000	<.001	.911	585.960	1.000
	Wilks' Lambda	.089	292.980[b]	2.000	57.000	<.001	.911	585.960	1.000
	Hotelling's Trace	10.280	292.980[b]	2.000	57.000	<.001	.911	585.960	1.000
	Roy's Largest Root	10.280	292.980[b]	2.000	57.000	<.001	.911	585.960	1.000

Table 7 shows that the experimental group achieved a higher posttest mean score than the control group. To evaluate the simultaneous effect of the learning models on scientific literacy and collaboration skills, we conducted a one-way MANOVA. The analysis revealed a statistically significant difference between the two groups (Wilks' \Lambda = 0.089, $F(2, 57) = 292.980$, $p < 0.001$, partial = 0.911). The partial eta squared value indicates that 91.1% of the variance in the combined dependent variables is explained by the instructional method, providing strong empirical evidence that integrating Edugames into Problem-Based Learning (PBL) effectively promotes both skills.

Following the significant multivariate result from the MANOVA, a follow-up univariate analysis (*Tests of Between-Subjects Effects*) was conducted. This analysis examined the specific impact of the learning models on each dependent variable individually, namely, scientific literacy and collaboration skills. Table 8 presents the detailed results of the univariate tests.

Table 8. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected	literasi_post	3792.150[a]	1	3792.150	443.407	<.001	.884	443.407	1.000
Model	kolaborasi_pos	4018.017[b]	1	4018.017	592.036	<.001	.911	592.036	1.000
Intercept	literasi_post	359290.817	1	359290.817	42011.022	<.001	.999	42011.022	1.000
	kolaborasi_pos	358981.350	1	358981.350	52894.195	<.001	.999	52894.195	1.000
group	literasi_post	3792.150	1	3792.150	443.407	<.001	.884	443.407	1.000
	kolaborasi_pos	4018.017	1	4018.017	592.036	<.001	.911	592.036	1.000
Error	literasi_post	496.033	58	8.552					

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
	kolaborasi_pos	393.633	58	6.787					
Total	literasi_post	363579.000	60						
	kolaborasi_pos	363393.000	60						
Corrected Total	literasi_post	4288.183	59						
	kolaborasi_pos	4411.650	59						

a. R Squared = .884 (Adjusted R Squared = .882)
b. R Squared = .911 (Adjusted R Squared = .909)
c. Computed using alpha = .05

The follow-up tests in Table 8 indicate that the instructional method has a significant impact on each variable individually. Integrating Edugames into Problem-Based Learning effectively enhances both students' scientific literacy and their collaboration skills independently compared to conventional instruction.

These results confirm that integrating Edugames into the PBL framework yields highly potent and significant benefits for both skills independently (Widana, 2022). Combining Problem-Based Learning with interactive game-based features appears to have facilitated deeper engagement and more meaningful learning experiences, which explains the higher achievement demonstrated by students in the experimental group. While PBL encouraged students to investigate authentic problems and construct knowledge independently, the Edugame enhanced engagement, motivation, and participation throughout the learning process. The combination of these approaches successfully created a student-centered learning environment that promoted both cognitive and social development To verify the assumption of homoscedasticity, a heteroscedasticity test was performed using the Glejser method by regressing the independent variables against the absolute residuals (ABS_RES). Table 9 summarizes the results.

Table 9. Coefficients of Heteroscedasticity Test

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.567	.627		5.689	<.001
	Group	-.767	.397	-.246	-1.933	.058

a. Dependent Variable: ABS_RES

According to the Glejser test results, the significance level for the independent variable against the absolute residuals (ABS_RES) is 0.397. Given that this value is greater than 0.05 ($0.397 > 0.05$), the model is free from heteroscedasticity. Thus, the homoscedasticity assumption is satisfied, and the regression model is deemed fit for use.

Edugame-supported Problem-Based Learning (PBL) significantly improved fifth-grade students' scientific literacy and collaboration skills, indicating that integrating interactive digital media with inquiry-based learning effectively strengthens both cognitive and social competencies. These findings are consistent with previous studies showing that technology-enhanced learning promotes scientific inquiry, conceptual understanding, and collaboration (Lei et al., 2024; Pavloff-Pelkonen et al., 2025; Laakso et al., 2021). However, Tokac et al. (2023) reported that the effectiveness of game-based learning varies across instructional contexts, possibly due to differences in intervention duration, learner characteristics, and technology integration. Structured implementation of Edugame within the Problem-Based Learning framework likely contributed to the stronger improvements observed in the present study (Widana & Umam, 2023).

Unlike previous studies that examined Problem-Based Learning or educational games separately and focused primarily on cognitive achievement or learning motivation, the present study shows that integrating both approaches strengthens scientific literacy and collaboration skills in elementary IPAS learning, as reflected in the exceptionally large treatment effect ($\eta p^2 = .985$). Theoretically, these findings extend technology-supported constructivist learning while supporting multimedia learning and game-based learning by demonstrating that interactive educational games promote meaningful knowledge construction, collaboration, and contextual problem-solving within inquiry-based instruction. Practically, the findings provide empirical guidance for teachers, schools, curriculum developers, and educational media designers to integrate Edugame-supported Problem-Based Learning into elementary science instruction to foster essential twenty-first-century competencies.

Conclusion

Edugame-supported Problem-Based Learning (PBL) significantly improved fifth-grade students' scientific literacy and collaboration skills, thereby providing clear answers to the research questions. Integrating problem-solving activities with interactive educational games created a meaningful learning environment that effectively fostered essential twenty-first-century competencies in elementary IPAS learning. This study's major contribution is demonstrating that integrating Edugame with Problem-Based Learning strengthens scientific literacy and collaboration skills while extending technology-supported constructivist learning in elementary science education. Based on these findings, elementary school teachers are encouraged to integrate Edugame-supported PBL into science instruction to promote active and collaborative learning. Future research should examine its effectiveness across different science topics, grade levels, educational settings, and longer intervention periods.

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