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The Effect of ICT-Integrated Problem-Based Learning on Students' Mental Models and Self-Efficacy in Science Education

Rahmi Hanifah[1*], Yanti Fitria[1]

[1] Basic Education, Universitas Negeri Padang, Padang, Indonesia.

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Corresponding Author:
Rahmi Hanifah
rahmihanifahpabar@gmail.com

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Abstract: This study examines the effect of Problem Based Learning (PBL) integrated with Information and Communication Technology (ICT) on students' mental models and self-efficacy in elementary school science learning. This study used a quantitative approach with a quasi-experimental nonequivalent control group design. The study population consisted of fourth-grade students in Cluster I, Pariaman Tengah District, in the 2024/2025 academic year, with two classes selected through purposive sampling as the experimental and control groups. Data were collected using a validated mental model test and self-efficacy questionnaire, then analyzed using descriptive and inferential statistics, including prerequisite tests and independent sample t-tests. The results showed that the experimental class obtained a higher mental model post-test score (79.17) than the control class (59.17). Self-efficacy scores increased significantly in the experimental group from 50.54 to 81.08, while the control group only reached 63.75. The results of statistical tests showed a significant difference between groups ($p < 0.05$). These findings indicate that ICT-integrated PBL is effective in improving students' conceptual understanding and self-confidence, thus becoming a relevant and innovative learning strategy to improve the quality of science learning in elementary schools.

Keywords: Information and Communication Technology (ICT); Mental models; Problem Based Learning; Science learning; Self-efficacy

Introduction

Science learning at the elementary school level plays a crucial role in preparing students to face the challenges of the Industrial Revolution 4.0 era, which demands that individuals possess scientific literacy, innovation, collaboration, and the ability to solve problems logically (Ayu et al., 2025; Azizah et al., 2025; Wulandari & Novita, 2018). Rapid technological advancements have driven educational reforms worldwide, including in Indonesia, where education policies continue to evolve to improve access, efficiency, effectiveness, and quality of education through technology integration. Therefore, educational practices must transform so that students acquire competencies relevant to the demands of today's and future society.

Natural Science (IPA) is a fundamental subject in elementary schools because it equips students with scientific thinking skills acquired through systematic processes such as observation, classification, experimentation, data interpretation, and communication using scientific methods (Miaz et al., 2023; Mustakim et al., 2019; Putri et al., 2025). This process enables students to understand natural phenomena and apply scientific concepts to solve real-life problems. Science learning is complex because it involves three interrelated levels of representation: macroscopic (observable phenomena), submicroscopic (particle-level explanations), and symbolic (models, formulas, or diagrams) (Andina et al., 2017). Students who are able to integrate these three representations will build a complete mental model, while those who are

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unable to do so will experience fragmented understanding and misconceptions. Thus, mental models can be an indicator of conceptual understanding as well as student learning difficulties.

In addition to mental models, self-efficacy is also a crucial factor influencing learning outcomes. Self-efficacy refers to an individual's belief in their ability to complete a task, which influences persistence, effort, and resilience in learning situations. Education policy also confirms that students' beliefs in their learning abilities significantly influence academic. Students with high self-efficacy tend to complete more assignments, demonstrate strong determination, and are more persistent when facing academic challenges. Therefore, learning environments need to be designed to simultaneously strengthen students' conceptual understanding and self-confidence (Damayanti et al., 2026).

One strategic effort to achieve these goals is the implementation of an appropriate learning model (Iftitah et al., 2023). Learning models are a crucial component of the learning process because they serve as a guide for teachers in organizing learning experiences, selecting methods, and facilitating student engagement (Mella et al., 2022; Nurjannah, 2022; Putri et al., 2025; Sukmawati et al., 2023). Teachers are required to be innovative and selective in selecting models that suit student needs and technological developments so that curriculum objectives can be achieved effectively. Among various approaches, Problem-Based Learning (PBL) integrated with Information and Communication Technology (ICT) is considered highly relevant to 21st-century learning because it encourages students to analyze problems, collaborate, think critically, and build knowledge through authentic experiences supported by digital technology (Mufit et al., 2025).

The integration of ICT in learning offers various advantages, such as global information access, flexibility in time and place, speed of data acquisition, and interactive multimedia presentations that can increase student motivation and understanding. Research shows that the combination of PBL and ICT can improve knowledge retention and create a more enjoyable learning experience for both teachers and students. This approach is very suitable for fifth-grade elementary school students who are in the transition stage from concrete operations to formal operations, where visualization, simulation, and contextual problem-solving greatly assist conceptual development (Arafah & Palloan, 2025; Harfiani & Setiawan, 2019; Puspita et al., 2024; Wariani et al., 2026).

However, despite its significant potential, empirical research on the integration of PBL and ICT at the elementary school level remains limited, particularly regarding its impact on students' mental models and self-efficacy. Most existing research focuses on the secondary education context, indicating a research gap that requires further study. A preliminary study conducted in three elementary schools in Pariaman Tengah District (SDN 08 Kampung Jawa I, SDN 17 Kampung Baru, and SDN 06 Cimparuh) showed that students' interest in science learning remains low because they consider the subject difficult and boring. The classroom learning process generally emphasizes only one level of representation, while submicroscopic and symbolic aspects receive less attention. As a result, students experience difficulties understanding concepts, analyzing contextual problems, and relating science learning to everyday life.

Interviews with teachers also showed that innovative learning models have not been widely implemented. Learning remains teacher-centered, with students spending most of their time listening, taking notes, and completing exercises from textbooks. Experimental activities are rare, digital media use is minimal, and assessments emphasize memorization over conceptual understanding. These conditions result in low cognitive achievement, weak mental models, and low student self-efficacy. Teachers acknowledged that they lack sufficient experience integrating technology-based models such as PBL with ICT, partly due to limited training, resources, and understanding of innovative learning strategies.

Given these various problems, learning innovations are needed that can encourage active student engagement, strengthen conceptual understanding, and increase self-confidence in learning science. The integration of Problem-Based Learning with ICT is expected to address these needs through the presentation of authentic problems, interactive learning experiences, and opportunities for students to construct knowledge collaboratively. This integration has the potential to improve critical thinking skills, learning motivation, and students' ability to solve scientific problems meaningfully.

Based on this background, the researcher is interested in conducting a study entitled "The Effect of ICT-Integrated Problem Based Learning Model on Students' Mental Models and Self-Efficacy in Elementary School Science Learning." The formulation of the research problem is: (1) Do students who are taught using ICT-integrated Problem Based Learning have better mental models compared to students who are taught using conventional learning models? (2) Do students who are taught using ICT-integrated Problem Based Learning have higher self-efficacy compared to students who are taught using conventional learning models?

Method

The researcher used experimental quantitative research techniques in this study. By analyzing the relationship between variables, quantitative research uses methodology to evaluate hypotheses. The research instrument measures variables so that numerical data can be analyzed using statistical calculation techniques. This research is a quasi-experimental study, so the Nonequivalent Control Group Design was used. Two classes, namely the experimental class and the control class, were used in this study. In this study, the experimental class will receive treatment in the form of learning using the ICT-integrated PBL learning model, while the control class will receive conventional learning. Quasi-experiments are also known as research that seeks to learn from experiments based on the treatment of the experiment within the design parameters set in the experimental class to collect data that accurately reflect what is expected (Sugiyono, 2013). The researcher presents the design table below to make it easier to understand this type:

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O1	X	O2
Control	O3	-	O4

Information :
O1 = pretest experimental class
O2 = posttest of experimental class
X = treatment within a certain time period
O3 = pretest control class
O4 = control class posttest
- = not given treatment

In this study, the population consisted of all fourth-grade students of Elementary Schools in Cluster I, Pariaman Tengah District, Pariaman City, in the 2024/2025 academic year, totaling 10 schools. The sampling technique used was purposive sampling (sampling with certain considerations). The sample selection criteria included similarities in school characteristics, the curriculum used, ICT-based learning facilities and infrastructure, and the average academic ability of students. Based on these criteria, the sample in this study was two classes at SDN 08 Kampung Jawa 1, one class as an experimental class and one class as a control class.

The data collection techniques in this study used test and questionnaire instruments. The test instrument was used to measure students' mental models through pretests and posttests, while the questionnaire was used to obtain data on students' self-efficacy after participating in the learning process. The test was designed based on Bloom's Taxonomy cognitive ability indicators (C1–C6) and adjusted to the learning outcomes of the science material. The questionnaire was designed to obtain comprehensive information regarding students' self-efficacy levels regarding the learning process.

Self-Efficacy Questionnaire

The research questionnaire was compiled by establishing indicators that support self-efficacy, namely: a) confidence in one's own abilities, b) resilience in facing difficulties, c) optimism in learning, d) ability to complete tasks, e) self-confidence during learning, f) courage to try new strategies, g) persistence in learning, and h) ability to overcome learning obstacles. Self-efficacy was measured by collecting respondents' answers to statement items using a Likert scale with five answer alternatives, namely Strongly Agree (SS), Agree (S), Undecided (R), Disagree (TS), and Strongly Disagree (STS). The assessment scores can be seen in Table 2.

Table 2. Alternative Scores for Self-Efficacy Questionnaire Answers

Answer Options	Positive	Negative
Strongly agree	5	1
Agree	4	2
Doubtful	3	3
Don't agree	2	4
Strongly Disagree	1	5

Before administering the questionnaire to the sample class, the instrument was first piloted in a class outside the research sample. The purpose of the pilot test was to determine the instrument's suitability for use as a valid and reliable data collection tool. The pilot test results were then analyzed to determine the validity and reliability of the statement items.

Validity of Questionnaire Items

The instrument's validity can be said to be valid if it can truly measure what it is supposed to measure. To validate a questionnaire, construct validity testing is used. Sugiyono (2013) explains that to test construct validity, researchers can use expert opinions. In this case, after the instrument has been constructed regarding the aspects to be measured based on a specific theory, it is then consulted with experts. Then, the experts are asked for their opinions on the instrument that has been developed. After that, the experts will provide a decision whether the instrument can be used without improvements, with improvements, or perhaps a complete overhaul. After the questionnaire trial, the researcher calculates the validity of each questionnaire statement item using the product moment correlation formula (Arikunto, 2013).

$$r_{xy} = \frac{N\sum XY-(\sum X)(\sum Y)}{\sqrt{\{N\sum X^2-(\sum X)^2\}\{N\sum Y^2-(\sum Y)^2\}}} \quad (1)$$

Information :
r_{xy} = Correlation coefficient
N = Number of samples studied
XY = Sum of the results of the total scores of respondents' answers questions and scores
$\sum X$= Total score of respondents' answers to each statement
$\sum Y$= Total score of each respondent's statement
$\sum X^2$= Sum of the total square scores of each respondent's answers statement
$\sum Y^2$= Sum of the squares of the total scores of the answers to each respondent's statement

Questionnaire Reliability

Reliability testing is conducted to determine the accuracy of the data collection tool used. This reliability is calculated using the Cronbach's Alpha formula, with a Cronbach's Alpha value greater than 0.05 indicating the variable is reliable. The formula is:

$$r_{11} = \left(\frac{n}{n-1}\right)\left(1-\frac{\sum s_i{}^2}{st^2}\right) \quad (2)$$

Information :
r_{11} = reliability coefficient
$\sum si^2$ = variance of the score of the i-th item
st^2 = total variance
n = number of questions

Table 3. Guidelines for Interpretation of Reliability Coefficient Criteria

Number	Information
0.800< $r_{11} \leq 1.00$	Very high
0.600 9< $r_{11} \leq 0.79$	Tall
0.400 9< $r_{11} \leq 0.59$	Currently
0.200 9< $r_{11} \leq 0.39$	Low
0.000 9< $r_{11} \leq 0.19$	Very low (not reliable)

Test Instrument

The second instrument in this study is a test.A test is a comprehensive assessment of an individual or an entire evaluation effort. Tests are used to measure a person's abilities and accomplishments. Test instruments are used to assess students' mental models in science learning. Tests are administered before the start of learning (pretest) and after the learning (posttest). The instrument development refers to Bloom's Taxonomy, first proposed by Benjamin S. Bloom. Researchers used Bloom's Taxonomy in developing tests because conceptual understanding is a key component of students' cognitive processes. This taxonomy aims to classify educational materials. The cognitive abilities in Bloom's Taxonomy consist of C1-C6 and are supported by Operational Verbs in test development.

Before being used, the test was first piloted to determine the validity, reliability, level of difficulty, and discriminatory power of the questions.

Distinguishing Power of Questions

The discriminatory power of a question refers to the question's ability to differentiate between students with high and low abilities (Sundayana, 2016). The formula used to calculate discriminatory power is:

$$DP = \frac{JBA-JBB}{JSa} \quad (3)$$

Information :
DP = Distinguishing power
JBA = Number of participants in the upper group who answered the question correctly
JBB = Number of participants in the lower group who answered the question correctly
JSa = Number of students in the upper group

Table 4. Classification of Distinguishing Power

Range	Category
DP ≤ 0.00	Very ugly
0.00 < DP ≤ 0.20	Bad
0.20 < DP ≤ 0.40	Enough
0.40 < DP ≤ 0.70	Good
0.70 < DP ≤ 1.00	Very well

Question difficulty index

The item difficulty index is an important criterion for classifying items as easy, medium, or difficult. For the test to be widely applicable, it is crucial to analyze the difficulty level of each item. According to Arikunto & Damayanti (2013), the formula used to determine the degree of difficulty.

$$P = \frac{B}{JS} \quad (4)$$

Information :
P = Difficulty index
B = Number of students who answered the question correctly
JS = Total number of students taking the test

Table 5. Difficulty index criteria

Range	Category
0.01 – 0.30	Difficult Questions
0.31 – 0.70	Medium Questions
0.71 – 1.00	Easy Questions

The third and fourth tests used in the pilot test were validity and reliability tests. The implementation procedures and analysis methods used in these two tests were detailed in the previous section on the learning motivation questionnaire analysis.

The initial stage of analyzing participants' mental model data was carried out by calculating the N-gain value to determine the extent of improvement in students' mental models and self-efficacy based on pre-test and post-test scores using the N-gain approach.

$$\text{N-gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}} \quad (5)$$

Table 6. N-Gain Score Categories

Gain score	Category
N- gain > 70	Tall
30 ≤ N- gain ≤ 70	Currently
N- gain < 30	Low

Data analysis was conducted in two stages, namely descriptive and inferential analysis. Descriptive analysis was used to describe data characteristics such as mean, median, mode, and standard deviation. Inferential analysis was used to test the research hypothesis using parametric statistics. Before testing the hypothesis, prerequisite tests were conducted in the form of a normality test using the Liliefors method and a homogeneity test using the F test to ensure the data were normally distributed and had homogeneous variance. If the conditions were met, then the hypothesis testing was carried out using the t-test. The entire data analysis process was carried out using SPSS software with a significance level of 0.05. The decision-making criteria were if the significance value (p) <0.05 then H_0 was rejected and H_1 was accepted, which means there was a significant effect of the given treatment.

Result and Discussion

Results

Description of Student Mental Model Data

The information presented comes from the pretest and posttest results of students in the experimental and control classes. This mental model test consists of 20 objective questions with varying levels of difficulty. In the form of distribution tables and histograms, the data description displays the mean, standard deviation, range of values, highest and lowest values, and central tendency. The following table provides information about the mental models of students in the experimental and control classes.

Table 7. Mental Model Value Data for Experimental and Control Classes

Description	Pretest Experimental Class	Posttest Experimental Class	Pretest Control Class	Posttest Control Class
Mean	43.12	79.17	46.88	59.17
Median	45.00	80.00	45.00	60.00
Mode	50	80	45	60
Standard Deviation	13,254	8,681	10,715	10,391
Variance	175,679	75,362	114,810	107,971
Range	55	35	50	45
Minimum	15	60	25	40
Maximum	70	95	75	85

The criteria below can be used to understand the results of the average value calculation.

A : 80 – 100 = Very Good
B : 66 – 79 = Good
C : 56 – 65 = Sufficient
D : 40 – 55 = Less
E : < 40 = Very Less

Pretest The experimental class is known to have an average value of 43.12, included in the less category, a median of 45, and a mode of 50. The average posttest value of the experimental class is 79.17 included in the good category with a median of 80 and a mode of 80. The pretest of the control class has an average score of 46.88 included in the less category with a median of 45, and a mode of 45. The posttest of the control class has an average value of 59.17 included in the sufficient category, has a median of 60, and a mode of 60.

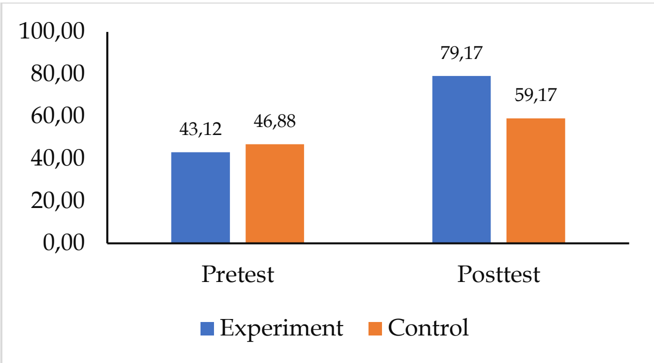

Figure 1. Mental Model Values of Students in the Experimental and Control Classes

The Figure 1 shows that the average pretest scores for the experimental and control classes are nearly identical. There is a significant difference between the average posttest scores for the experimental and control classes. The average posttest score for the experimental class is higher than the control class, at 79.17.

Description of Student Self-Efficacy Data

The data described are the results of pre- and post-learning questionnaires in the experimental and control classes. The self-efficacy questionnaire consists of 15 statements. In the form of a distribution table and histogram, the data description displays the average, standard deviation, range of values, highest and lowest values, and central tendency. The following table provides information on the self-efficacy of students in the experimental and control classes.

Table 8. Data on Self-Efficacy Values of Students in the Experimental and Control Classes

Description	Before Experimental Class Learning	After Experimental Class Learning	Before Control Class Learning	After Control Class Learning
Mean	50.54	81.08	51.92	63.75
Median	50.00	81.00	49.00	63.00
Mode	53	83	48	63
Standard Deviation	6.672	5.437	7.372	7.134
Variance	44.520	29.558	54.341	50.891
Range	29	20	31	31
Minimum	35	72	36	53
Maximum	64	92	67	80

The average self-efficacy score of students before the experimental class was 50.54, which is considered poor. After the experimental class, the average self-efficacy of students reached 80.08, which is considered very good. The average self-efficacy score of students in the control class before the learning was 51.92, which is considered poor. After participating in the control group, the average self-efficacy score of students was 63.17, placing them in the sufficient category.

To clarify the above results, a histogram of the data is presented as follows:

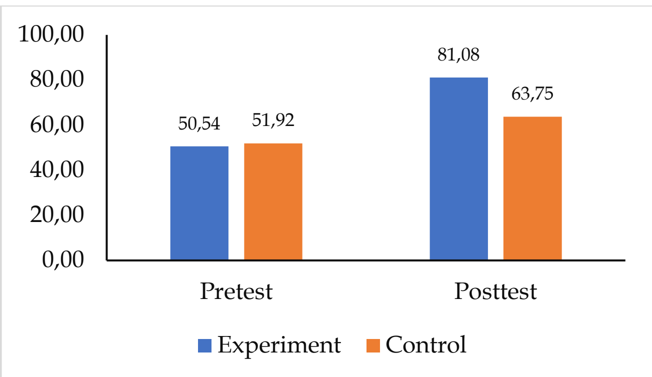

Figure 2. Self-efficacy Ability Values of Students in the Experimental and Control Classes

The image above shows that the average self-efficacy scores of students before the experimental and control classes were not much different, namely 50.54 and 51.92. The average self-efficacy scores of students after the experimental and control classes were significantly different, namely the average score after the experimental class was higher than the control class, namely 81.08.

N-Gain Value

N-Gain Mental Models of Students

The Table 9 shows that the N-gain value of the Mental model of the experimental class is better than the control class. There is a difference in the N-gain value of the two classes, namely in the control class the N-gain of the Mental model is in the low category, while in the experimental class the N-gain value is in the medium category. The following is a histogram of the N-gain value of the Mental model of students in the experimental and control classes.

Table 9. N-Gain Value of Students' Mental Models

Class	N-Gain Value	Category
Experiment	0.634	Currently
Control	0.231	Low

The Figure 3 shows that the N-gain value of the mental model of the experimental class students is much better than the control class, with a value of 0.634 and 0.231. The difference between these two values is quite large, namely 0.324, which means there is a difference in the mental models of the experimental class and the control class students.

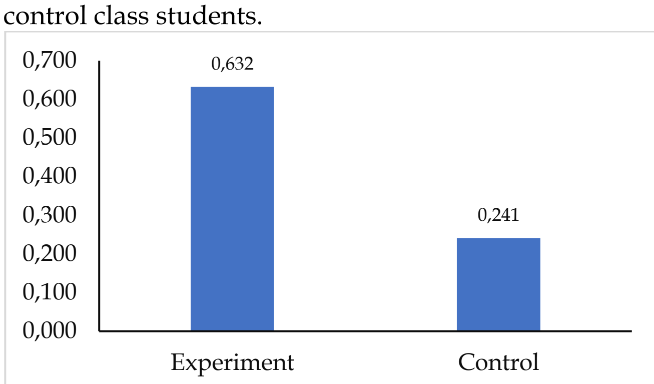

Figure 3. N-Gain Value of Students' Mental Model

N-Gain Self-efficacy of Students

The Table 10 shows that the N-gain self-efficacy value of the experimental class is better than the control class. The N-gain values of both classes are in the moderate category, but there is a visible difference in the N-gain values between the experimental and control classes. The following is a histogram of the N-gain self-efficacy values of students in the experimental and control classes.

Table 10. N-Gain Self-efficacy Values of Students

Class	N-Gain Value	Category
Experiment	0.619	Currently
Control	0.245	Low

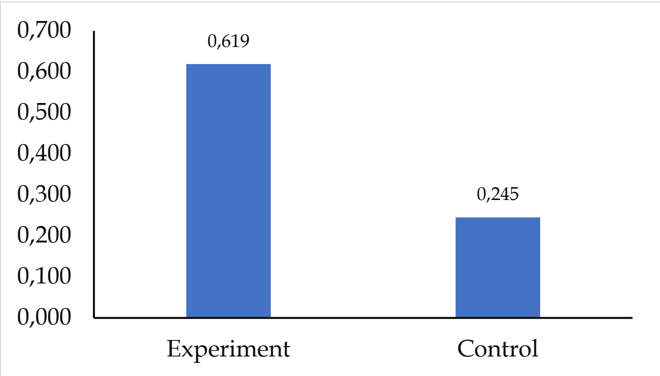

Figure 4. Student Self-efficacy N-Gain Value

The Figure 4 shows that the N-gain self-efficacy value of students in the experimental class is better than the control class, with a value of 0.619 and 0.245. The difference between these two values is quite large, namely 0.374, which means there is a difference in self-efficacy between students in the experimental class and the control class.

Data Normality Test Mental Model Test

Based on the Table 11, the results of the normality test for the experimental class obtained a significance of 0.889 or greater than 0.05 (0.889 > 0.05), while the results of the normality test for the control class obtained a significance of 0.433 or greater than 0.05 (0.433 > 0.05). So it can be concluded that the initial data values (pretest) of students in the experimental class and the control class are normally distributed.

The results of the normality test for the experimental class obtained a significance of 0.240 or greater than 0.05 (0.240 > 0.05), while the results of the normality test for the control class obtained a significance of 0.139 or greater than 0.05 (0.139 > 0.05). So it can be concluded that the final data values (posttest) of students in the experimental class and the control class are normally distributed.

Table 11. Normality of Mental Model Test Data

Class	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	Df	Sig.
Experiment Pretest	0.115	24	0.200*	0.980	24	0.889
Pretest Control	0.170	24	0.071	0.960	24	0.433
Experiment Posttest	0.194	24	0.019	0.948	24	0.240
Posttest Control	0.218	24	0.006	0.937	24	0.139

Normality Test of Self-Efficacy Questionnaire Data

Based on the table above, the results of the data normality test before learning in the experimental class obtained a significance of 0.662 or greater than 0.05 (0.662 > 0.05), while the results of the control class normality test obtained a significance of 0.346 or greater than 0.05 (0.346 > 0.05). So it can be concluded that the questionnaire data values before learning were normally distributed.

The results of the normality test for data after learning in the experimental class obtained a significance of 0.365 or greater than 0.05 (0.365 > 0.05), while the results of the normality test for the control class obtained a significance of 0.039 or greater than 0.05 (0.039 > 0.05). So it can be concluded that the questionnaire data values after learning are normally distributed.

Table 12. Normality of Self-efficacy Questionnaire Data

Class	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Sig.	Statistics	df	Sig.
Before Experimental Class Learning	.148	24	.188	.970	24	.662
Before Control Class Learning	.129	24	.200*	.955	24	.346
After Experimental Class Learning	.195	24	.068	.956	24	.365
After Class Control Learning	.194	24	.060	.912	24	.039

Homogeneity Test Mental Model Test Data

Based on the table above, the homogeneity test of the mental model test (pretest-posttest) in the experimental class and the control class obtained a significance value of 0.609 or greater than 0.05 (0.609 > 0.05), a statistical level of 0.265, so it can be concluded that the mental model test data has the same or homogeneous variance.

Table 13 Homogeneity of Mental Model Test Data

Levene Statistics	df1	df2	Sig.
0.265	1	46	0.609

Homogeneity Test Self-efficacy Questionnaire Data

Based on the table above, the homogeneity test of the self-efficacy questionnaire data (before-after learning) in the experimental class and the control class obtained a significance value of 0.507 or greater than 0.05 (0.507 > 0.05), a statistical level of 0.448, so it can be concluded that the self-efficacy questionnaire data has the same or homogeneous variance.

Table 14. Homogeneity of Self-Efficacy Questionnaire Data

Levene Statistics	df1	df2	Sig.
0.448	1	46	0.507

First Hypothesis

The first hypothesis in this study is that there is a difference in the use of the Integrated Problem Based Learning (PBL) Information, Communication, and Technology (ICT) learning model with the conventional learning model on students' Mental Models in Science learning on the subject of Harmony in Ecosystems. To answer this hypothesis, a t-test was conducted using the SPSS application with a sig. 5%.

Table 15. Pretest Data t-Test

Parameters	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	2.059	0.158	-1.078	46	0.287	-3.750	3.479	-10.753	3.253
Equal variances not assumed			-1.078	44.065	0.287	-3.750	3.479	-10.761	3.261

Based on the initial data table (pretest) above, the significance value of Sig. is 0.287 > 0.05, so according to the basis for decision making, it is obtained that H0 is accepted and Ha is rejected, which means there is no difference in the use of the ICT-integrated PBL learning model with the use of the conventional learning model on students' mental models in science learning on the subject of Harmony in Ecosystems in the initial data (pretest). Next, a t-test was conducted on the final value data (posttest) of students. The test results are presented in the Table 16.

Table 16. Posttest Data t-Test

Parameters	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.198	.659	7.236	46	.000	20.000	2.764	14.437	25.563
Equal variances not assumed			7.236	44.589	.000	20.000	2.764	14.432	25.568

Based on the final data table (posttest) above, the significance value of Sig. is 0.000 < 0.05, so according to the basis for decision making, H0 is rejected and Ha is accepted, which means there is a difference in the use of the ICT-integrated PBL model with the use of the conventional learning model on students' Mental Models in Science learning on the subject of Harmony in Ecosystems in the final data (posttest).

From the table above, it can be seen that the correlation value R is 0.578 and the R square value is 0.334, which means that the influence of the ICT-integrated PBL learning model on the Mental Model is 33.4%.

Table 17. Coefficient of Determination

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	0.578	,334	0.303	7.295

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	41.985	16.037		1.176	0.016
	X	0.511	0.199	0.026	0.122	0.001

Based on the table above, the constant value (a) is 41.985 and the regression coefficient value (b) is 0.511 so that the regression equation can be written:

Y = a + bX

Y = 41.985 + 0.511 X

The equation above can be interpreted that the constant of 41.985 means that the consistency value of this variable is 41.985. The regression coefficient X of 0.511 states that the coefficient of determination is positive, so it can be said that the direction of the positive influence of the ICT-integrated PBL learning model on the Mental Model because the coefficient of determination is getting closer to 1. The greater the coefficient of determination (approaching 1), the better the results for the regression model and the closer it is to 0, the regression model being tested does not have good results.

Second Hypothesis

The second hypothesis in this study is that there is an influence of the use of Integrated Problem Based Learning Information, Communication, and Technology on students' self-efficacy in science learning on the subject of Harmony in Ecosystems. To answer this hypothesis, a t-test was conducted using the SPSS application with a significance level of 5%.

Table 18. t-Test of Questionnaire Data Before Learning

Parameters	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.865	.357	-.677	46	.501	-1.375	2.029	-5.460	2.710
Equal variances not assumed			-.677	45.551	.502	-1.375	2.029	-5.461	2.711

Based on the questionnaire data table before the learning above, the significance value of Sig. is 0.501 > 0.05 and 0.502 > 0.05, so according to the basis for decision making, it is obtained that H0 is accepted and Ha is rejected, which means there is no effect of the use of the Integrated Problem Based Learning Information, Communication, and Technology learning model on students' Self-Efficacy in Science learning on the Harmony in Ecosystem material before learning (before being given treatment). Next, a t-test was conducted on the final questionnaire score data after treatment was given to students. The test results are presented in the Table 19.

Based on the questionnaire data table after the learning above, the significance value of Sig. is 0.000 <0.05, so according to the basis for decision making, it is obtained that H0 is rejected and Ha is accepted, which means that there is an influence of the use of the Integrated Problem Based Learning Information, Communication, and Technology learning model on students' Self-Efficacy in science learning on the subject of Harmony in Ecosystems.

Table 19. t-Test of Questionnaire Data After Learning

Parameters	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	.506	.481	9.467	46	.000	17.333	1.830	13.648	21.019
Equal variances not assumed			9.467	42.978	.000	17.333	1.830	13.640	21.026

From the Table 20, it can be seen that the correlation value R is 0.681 and the R square value is 0.477, which means that the influence of the ICT-integrated PBL learning model on students' self-efficacy is 47.7%.

Based on the table above, the constant value (a) is 49.232 and the regression coefficient value (b) is 0.603 so that the regression equation can be written:

Y = a + bX

Y = 49.232 + 0.603X

The equation above can be translated that the constant of 49.232 means that the consistency value of this variable is 49.232. The regression coefficient X of 0.603 states that the coefficient of determination is positive, so it can be said that the direction of the positive influence of the ICT-integrated PBL learning model on students' Self-Efficacy because the coefficient of determination is getting closer to 1.

Table 20. Coefficient of Determination

Model		R	R Square	Adjusted R Square	Standard Error of the Estimate
1		0.681	0.477	0.235	5.950

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	49.232	22.756		2,163	,042
	X	0.603	0.282	0.066	,049	,000

Discussion

The results of the study showed that after normality and homogeneity tests, the experimental and control classes had equivalent initial conditions. This was proven through the equality of two means (pretest) test, which showed no significant differences between the two classes. This equality of initial conditions is important in experimental research because it ensures that differences in final results are truly caused by the treatment, not by differences in students' initial abilities. According to Sugiyono (2017), similarity of initial conditions is a prerequisite for the internal validity of experimental research so that the results obtained can be interpreted objectively.

The experimental class received treatment in the form of the application of the ICT-integrated Problem Based Learning (PBL) learning model on the Harmony in Ecosystems material, while the control class used conventional learning. The stages of the ICT-integrated PBL implemented include technology-based problem orientation, learning organization, independent and group investigations using ICT, presentation of work results, and reflection and evaluation of the problem-solving process (Abdul, 2021; Ayu et al., 2025; Elvistoni & Ardiansyah, 2024; Furkan & Yanti, 2023; Suarlin et al., 2025). These stages are in accordance with the PBL syntax according to Kusnandar et al., (2025) which emphasizes authentic problem-based learning, active investigation, and presentation of solutions as the core of constructivist learning.

Descriptively, the results of the students' Mental Model test showed an advantage for the experimental class compared to the control class. The average pretest scores for both classes were relatively equal (46.88 and 43.12), but there was a significant difference in the posttest, where the experimental class obtained an average of 79.17 while the control class obtained 59.17. This improvement indicates that the implementation of ICT-integrated PBL can help students build better conceptual representations. This is in line with the theory of cognitive constructivism which states that conceptual understanding is formed through an active process of building knowledge based on learning experiences (Angglepi et al., 2025; Aprianti et al., 2025; Azzahra et al., 2025; Haki et al., 2024; Sape et al., 2024). Research by Kurniati & Arafah, (2025) also reported that technology-assisted problem-based learning can improve the quality of students' mental models because it provides contextual learning experiences and visualization of abstract concepts.

In addition to Mental Models, students' Self-Efficacy also experienced a significant increase in the experimental class. The average Self-Efficacy score increased from 50.24 to 81.08, while in the control class it only increased from 51.92 to 63.75. These results indicate that ICT-integrated PBL impacts not only cognitive aspects but also affective aspects. Rampisela, (2025) explains that self-efficacy develops through successful experiences, social interactions, and a challenging yet supportive learning environment. A problem-based learning environment with technological support allows students to gain successful problem-solving experiences, thereby increasing their academic self-confidence. Putra et al. (2023) also found that technology integration in problem-based learning can significantly increase students' learning confidence.

The N-Gain analysis shows that the increase in Mental Model in the experimental class (0.634) is higher than the control class (0.231) with a difference of 0.403. Similarly, the increase in Self-Efficacy in the experimental class (0.619) is higher than the control class (0.245) with a difference of 0.374. Based on Hake (1999) effectiveness category, an N-Gain value above 0.6 is included in the high category, so it can be concluded that the learning intervention has a strong impact (Jamaludin et al., 2022; Sadiah & Ali, 2025; Supriati et al., 2025). This finding is consistent with research Azizah et al., (2025) who reported that ICT-assisted PBL learning resulted in high category learning outcomes because it combined problem-solving activities with interactive digital visualizations.

The results of the hypothesis test support these findings. The first hypothesis obtained a significance value of 0.000 < 0.05, indicating that the ICT-integrated PBL model has a significant effect on students' Mental Models. The correlation coefficient value of R of 0.578 indicates a moderate relationship, while the R^2 value of 0.334 indicates that the contribution of the learning model to Mental Models is 33.4%. The positive regression coefficient (0.511) indicates that the more optimal the model implementation, the higher the students' Mental Models. These results are in line with research. Pratama & Sari, (2026) which states that the PBL model has a real contribution to increasing conceptual understanding because it requires students to construct knowledge independently.

In the second hypothesis, a significance value of 0.000 < 0.05 indicates that the ICT-integrated PBL model also has a significant effect on self-efficacy. The R value of 0.681 indicates a strong relationship, while the R^2 value of 0.477 indicates a contribution of 47.7%. The positive regression coefficient (0.603) indicates that improving the quality of model implementation will increase students' self-efficacy. This finding is in line with research. Arman et al. (2025) which states that problem-based learning supported by digital technology significantly increases students' motivation, self-confidence, and learning engagement.

Research findings demonstrate that the use of ICT-integrated PBL learning models is effective in improving students' Mental Models and Self-Efficacy in the Harmony in Ecosystems topic. The integration of technology in PBL provides visual, interactive, and contextual problem presentations, facilitating conceptual understanding while increasing learning motivation. This aligns with multimedia learning theory, which states that the combination of text, images, animation, and digital interaction can enhance information processing and knowledge retention (Mayer, 2021; Suharlan et al., 2023). In addition, the use of ICT also supports 21st-century learning that emphasizes critical thinking skills, collaboration, creativity, and digital literacy (Abas et al., 2024; Akib et al., 2020; Febrina & Mukhidin, 2019; Mashudi, 2021; Megawati & Sofiroh, 2025; Nurazizah et al., 2025; Ramadhan et al., 2025; Utami et al., 2025).

The findings of this study have important implications for educational practice, particularly in science instruction in elementary schools. Teachers are advised to integrate the PBL model with learning technology, as it has been proven to simultaneously enhance cognitive and affective aspects. Implementing this model can also serve as an alternative, innovative learning strategy that aligns with the demands of modern curricula that emphasize active, student-centered learning.

This study has several limitations. First, the assessment focused solely on Mental Models and Self-Efficacy, thus not including other variables such as scientific literacy, critical thinking skills, or creativity. Second, control over sample characteristics was limited, so factors outside the treatment, such as academic background and initial technological skills, were not analyzed in depth. Future research is recommended to include more diverse variables, a larger sample size, and a longer treatment duration to obtain a more comprehensive picture of the model's effectiveness.

Conclusion

This study shows that the implementation of the Problem Based Learning (PBL) learning model integrated with Information and Communication Technology (ICT) has been proven to have a significant influence on improving the mental models and self-efficacy of elementary school students in science learning. The analysis results show that this model contributes 33.4% to the mental model and 47.7% to self-efficacy, which indicates that the integration of PBL and ICT is an effective innovative approach in supporting 21st-century learning. These findings prove that the use of technology-supported problem-based learning can increase student engagement, strengthen conceptual understanding, and foster self-confidence in learning. Teachers are advised to implement the ICT-integrated PBL model as part of routine learning strategies. Further development can be directed at the use of more diverse digital technologies and integration with other models or approaches so that the scope of application and its impact on improving student competencies are wider

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Conceptualization; methodology.; R. H.; validation; formal analysis; Y. F.; investigation; R. H.; resources; R. H.; data curation: writing—original draft preparation; writing—review and editing.; R. H.; visualization: Y.F. All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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