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The Application of a Problem-Based Learning Model Using The Experimental Method on The Learning Outcomes and Scientific Reasoning Skills of Elementary School Students in Science Education

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ABSTRACT: Science learning in elementary schools requires students to understand concepts through observation, investigation, and reasoning processes. However, students' learning outcomes and inference skills are still relatively low because learning activities are often dominated by teacher explanations and have not fully involved students in scientific inquiry activities. This study aims to analyze the effect of the Discovery Learning model assisted by Live Worksheet on students' learning outcomes and inference skills in science learning on the topic of changes in states of matter.
This study employed a quantitative approach with a quasi-experimental method using a Nonequivalent Control Group Design. The research subjects were fourth-grade students of SD Negeri Antirogo 01 and SD Negeri Antirogo 04, Jember Regency, consisting of 62 students. The experimental class received treatment through Discovery Learning assisted by Live Worksheet, while the control class received conventional learning. Data collection techniques used learning outcome tests and inference skill instruments. Data analysis was performed through prerequisite tests and hypothesis testing using inferential statistics.
The results showed that the Discovery Learning model assisted by Live Worksheet had a significant effect on students' learning outcomes and inference skills. The learning process encouraged students to actively observe, collect information, process data, verify findings, and formulate conclusions based on evidence. The integration of interactive digital worksheets strengthened students' involvement and supported meaningful learning experiences. Therefore, Discovery Learning assisted by Live Worksheet can be an effective alternative strategy to improve cognitive achievement and scientific thinking skills among elementary school students.

KEYWORDS: discovery learning, elementary school, inference skills, live worksheet, learning outcomes, science learning

INTRODUCTION

Basic education is a crucial foundation for shaping students' character and cognitive potential. According to Ministry of Education and Culture Regulation No. 13 of 2025, the curriculum aims to enhance faith, piety toward God the Almighty, citizenship, critical thinking, creativity, collaboration, independence, health, and communication, as well as to foster students' creativity, sensitivity, and initiative as lifelong learners embodying the values of Pancasila through Deep Learning. Upon closer examination, in line with these objectives, 21st-century education demands innovation in the learning process to prepare students to face increasingly complex global challenges (Humayra et al., 2025).

Based on the results of preliminary observations and a literature review, the fundamental problem in IPAS learning in most elementary schools is, first, learning outcomes. According to Ropii & Fahrurrozi (2017), learning outcomes are essentially the achievements students attain after studying course material in school, which are expressed in the form of grades or test scores. Student learning outcomes in science—particularly those requiring conceptual understanding and the interrelationships among phenomena—remain relatively low. Instruction focuses on memorizing facts and definitions rather than on a deep understanding of scientific processes and principles. Second, scientific reasoning skills. To support improvements in the quality of science education, students are expected to master scientific reasoning skills, which are a key competency in the learning process and contribute positively to reasoning activities (Fadlilah et al., 2024). Scientific reasoning is not innate but develops through interaction with various factors, one of which is the science teaching strategies used by teachers (Hadi et al., 2021).

Students' reasoning skills—which include formulating hypotheses, designing investigations, analyzing data, and drawing conclusions based on evidence—are also underdeveloped. Students often struggle to connect theory with facts, as well as to

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analyze and evaluate a problem systematically. These two issues are interrelated; poor scientific reasoning hinders deep conceptual understanding, which ultimately leads to unsatisfactory learning outcomes. According to Jean Piaget's theory of cognitive development, elementary school-aged children (7–12 years old) are generally in the Concrete Operational stage. At this stage, children begin to think logically, but only regarding concrete, real, and directly observable objects or events. They experience significant difficulty in understanding abstract, hypothetical, or purely verbal concepts (And His School, n.d.)

The root of this problem is strongly suspected to lie in a learning approach that remains conventional and teacher-centered. Lecture-based methods and text-based assignments still dominate, leaving little room for students to construct their own knowledge through direct experience and making learning tedious (Pada et al., 2025). Experimental or laboratory-based learning remains largely verification-oriented, where students merely follow predetermined steps without being critically engaged in designing or questioning the process. As a result, students become passive, unmotivated, and unaccustomed to thinking scientifically when solving problems. Student academic achievement can be improved through the implementation of appropriate teaching methods. Teachers need to plan learning activities carefully, particularly when selecting methods that align with the material being taught. In the process of selecting methods, teachers must align learning objectives with the desired student behaviors (Anggraini, 2021).

Student academic achievement can be improved through the use of appropriate teaching methods. Teachers need to plan learning activities carefully, particularly when selecting methods that align with the material being taught. In the process of selecting methods, teachers must align learning objectives with the desired student behaviors (Anggraini, 2021). Therefore, an innovative learning model is needed that can address both issues simultaneously. The Problem-Based Learning (PBL) model has emerged as a potential solution.

PBL is a learning model that uses contextual and real-world problems as the starting point for learning. Dale's Cone of Experience theory asserts that students' active engagement in learning activities helps them more easily understand and retain the material being studied (A. E. Putri et al., 2024). Through PBL, students are encouraged to identify problems, ask questions, investigate, and collaboratively find solutions. This model is intrinsically designed to develop critical thinking and problem-solving skills. To strengthen the scientific dimension in IPAS learning, the PBL model needs to be integrated with authentic experimental methods. In this integration, experiments are no longer merely teacher demonstrations or routine activities but become investigative tools designed by students (with teacher guidance) to answer the questions or address the problems they face. The PBL framework (from orienting students to the problem to presenting results) will be combined with the steps of the scientific method in experiments. The application of experimental methods integrated with the PBL model will create a more engaging and meaningful learning experience for students.

Based on the above discussion, this study was conducted to empirically examine the effect of implementing the Problem-Based Learning (PBL) model using an experimental method on the learning outcomes and scientific reasoning skills of elementary school students in science education. The findings of this study are expected to provide scientific evidence and practical recommendations for educators in their efforts to improve the quality of active, creative, and meaningful learning in line with the policy direction of the Merdeka Curriculum.

This study focuses on analyzing the impact of implementing the Problem-Based Learning (PBL) model combined with the experimental method on two key aspects of elementary school students. The focus of the study is formulated into two main questions. First, this study examines whether the combination of the PBL model and the experimental method has a significant effect on improving students' learning outcomes. Second, the study also aims to further explore the effect of implementing the PBL model on students' scientific reasoning skills at the elementary school level.

MATERIALS AND METHODS (OR METHODOLOGY)

This study employed a quasi-experimental research method (Quasi-Experimental Design) using a Nonequivalent Control Group Design. According to Olamsyah et al. (2020), this design involves two groups that both take a pretest (O) to determine their initial conditions. During the study, the first group received the treatment (X), while the other group did not. The group that received the treatment served as the experimental group, while the group without treatment served as the control group. At the end of the study, both groups were given a posttest (O) to determine the results obtained.

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In this study, there were two groups: the experimental group, which received instruction using the IPAS Problem-Based Learning (PBL) model combined with the experimental method, The control group received IPAS instruction using a conventional approach (lectures and assignments). To ensure the validity of the study, the equivalence of the two groups' initial abilities was tested before the treatment was administered. The researcher used the first-semester final exam scores.

In this study, the independent variable is the implementation of the Problem-Based Learning (PBL) model using an experimental method, denoted by the symbol (X). The dependent variables consist of two aspects: students' IPAS learning outcomes (Y_1) and their scientific reasoning skills (Y_2). In addition, this study also involves control variables, which include instructional materials, learning time allocation, the teaching teacher, and classroom facilities and infrastructure. These control variables were kept constant so that the effect of the independent variable on the dependent variables could be measured more objectively.

The sample was selected using purposive sampling, which involved selecting two classes with relatively similar characteristics (number of students, prior knowledge, and learning facilities). This technique was chosen because the researcher could not alter the composition of classes that had already been formed at the school in order to maintain a conducive learning environment. Class V-A served as the control class, and Class V-B as the experimental class. The research sample consisted of two classes: Class VA, the control class, which used a conventional learning model consisting of lectures and assignments; and Class VB, the experimental group, which was treated with the Problem-Based Learning (PBL) model using an experimental method.

1. Initial Stage (Input)

The researcher collected semester grade data for both classes. This stage served as a substitute for a pretest to ensure that the control class had equivalent initial abilities through statistical tests (normality and homogeneity).

2. Treatment Phase (Process)

The experimental group was taught using the Problem-Based Learning (PBL) model with an experimental approach, while the control group used the conventional model. Both groups received the same IPAS material.

3. Final Phase (Output)

Both groups were given the same post-test. The scores obtained were then analyzed using a MANOVA test to examine the effect of the treatment on two dependent variables simultaneously: learning outcomes and scientific reasoning skills.

RESULTS

Analysis of Post-Test Results

After the intervention, both classes took a post-test to measure learning outcomes and scientific reasoning skills. A summary of the post-test results is presented as follows:

Table 4.1 Summary of Post-Test Results for the Experimental and Control Classes

Statistics	Experimental Class (5B)	Control Class (5A)
Learning Outcomes		
Highest Score	100	93
Lowest Score	61	60
Total	2,263	1,913
Mean	87.03	73.58
Scientific Reasoning		
Highest Score	98	90
Lowest Score	63	11
Total	2,190	1,677
Mean	84.23	64.50

Table 4.1 shows that the average learning achievement of students in the experimental class (87.03) was higher than that of the control class (73.58), with a difference of 13.45 points. Similarly, the average scientific reasoning ability of students in the experimental class (84.23) was higher than that of the control class (64.50), with a difference of 19.73 points.

Analysis of the Effect of the Problem-Based Learning (PBL) Model Using the Experimental Method on Learning Outcomes (Y_1)

This analysis aims to test whether there is a significant difference in IPAS learning outcomes between students who participated in the PBL model using the experimental method and those who participated in conventional learning.

a. Normality Test of Learning Outcome Data

The normality test was conducted using the Shapiro-Wilk test because the sample size for each group was 26 students ($n < 50$). Data is considered normally distributed if the significance value (Sig.) is > 0.05; if the significance value (Sig.) is < 0.05, the data is not normally distributed. The results of the normality test for the post-test learning outcomes data are shown in the following table.

Table 4.2 Results of the normality test for post-test learning achievement data

Class	Statistic	df	Sig.	Interpretation
Experimental Class (Post-test)	0.829	26	0.001	Not Normally Distributed
Control Class (Post-test)	0.931	26	0.081	Normally Distributed

Based on the table above, the significance value (Sig.) for the posttest data of the experimental class was 0.001, which means that this value is less than 0.05 (0.001 < 0.05). This indicates that the posttest data on learning outcomes for the experimental class are not normally distributed. Meanwhile, the significance value for the control class's post-test data is 0.081, which is greater than 0.05 (0.081 > 0.05); therefore, the control class's post-test learning achievement data is normally distributed.

Consequently, since one of the data groups (the experimental class) is not normally distributed, the hypothesis test used in this study is not a parametric test (Independent Samples t-Test) but rather a non-parametric test—specifically, the Mann-Whitney U test—as an alternative test to determine the difference in learning outcomes between the experimental and control classes.

Test Statistics[a]

	Postes Hasil Belajar KlsEks
Mann-Whitney U	102.000
Wilcoxon W	453.000
Z	-4.357
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Postes Hasil Belajar KlsKon

Nilai Asymp. Sig. (2-tailed) yang diamati adalah 0,000. Nilai ini dibandingkan dengan tingkat signifikansi sebesar 0,05. Karena 0,000 < 0,05, H0 ditolak dan H1 diterima. Terdapat perbedaan yang signifikan antara hasil belajar (tes akhir) kelas eksperimen dan kelas kontrol. Hal ini berarti bahwa setelah perlakuan diberikan, kinerja akhir kedua kelas tersebut tidak lagi setara; terdapat perbedaan yang jelas di antara keduanya.

b. Uji Hipotesis mengenai Pengaruh terhadap Hasil Belajar

Karena asumsi normalitas tidak terpenuhi, uji perbedaan rata-rata dilakukan menggunakan uji Mann-Whitney U. Uji Mann-Whitney U dipilih karena lebih tangguh untuk data yang tidak normal. Hipotesis yang diuji adalah:

- H_0: Tidak ada perbedaan yang signifikan dalam hasil belajar antara kelas eksperimen dan kelas kontrol.
- H_1: Terdapat perbedaan yang signifikan dalam hasil belajar antara kelas eksperimen dan kelas kontrol.

Tabel 4.4 Hasil Uji Mann-Whitney U terhadap Data Hasil Belajar

Variable	Mann–Whitney U	z	Asymp. Sig. (2-tailed)	Interpretation
Learning Outcomes	102.000	-4.357	0.000	Significant

Berdasarkan Tabel 4.4, diperoleh nilai *Asymp. Sig. (2-tailed)* sebesar 0,000. Karena nilai ini lebih kecil dari 0,05 (0,000 < 0,05), maka H_0 ditolak dan H_1 diterima. Hal ini menunjukkan bahwa terdapat perbedaan yang signifikan antara hasil belajar IPAS siswa yang mengikuti model PBL dengan metode eksperimen dibandingkan dengan siswa yang mengikuti pembelajaran konvensional. Dengan demikian, dapat disimpulkan bahwa penerapan model PBL dengan metode eksperimen memberikan pengaruh yang signifikan terhadap peningkatan hasil belajar siswa.

Analysis of the Effect of the *Problem-Based Learning* (PBL) Model Using the Experimental Method on Scientific Reasoning Ability (Y_2)

This analysis aims to test whether there is a significant difference in scientific reasoning ability between students who participated in the PBL model using the experimental method and those who participated in conventional learning.

a. Normality Test of Scientific Reasoning Data

As before, the normality test was conducted using the Shapiro-Wilk test.

Table 4.5 Results of the Normality Test for Post-Test Scientific Reasoning Data

Class	Statistic	df	Sig.	Interpretation
Experimental Class	0.906	26	0.021	Not Normally Distributed
Control Class	0.938	26	0.118	Normally Distributed

The normality test for the post-test data on scientific reasoning ability was conducted using the Shapiro-Wilk test with the aid of SPSS, with the following test criteria: if the significance value (Sig.) is > 0.05, the data are normally distributed; and if the significance value (Sig.) is < 0.05, the data are not normally distributed.

Based on the results of the normality test, the significance value for the experimental class was 0.021 (< 0.05), indicating that the post-test data on scientific reasoning for the experimental class were not normally distributed. Meanwhile, the significance value for the control class was 0.118 (> 0.05), indicating that the post-test data on scientific reasoning for the control class were normally distributed.

b. Hypothesis Test on the Effect on Scientific Reasoning

Since one of the data groups (the experimental class) is not normally distributed, the hypothesis test used in this study is not a parametric test (Independent Samples t-Test) but rather a non-parametric test, namely the Mann-Whitney U test, as an alternative test to determine the difference in scientific reasoning ability between the experimental and control classes.

Table 4.6 Results of the Rank Table

Class	N	Mean Rank	Sum of Ranks
Experimental Class	26	34.88	907.00
Control Class	26	18.12	471.00

Test Statistics Table Results:

- Mann-Whitney U = 120,000
- Wilcoxon W = 471,000
- Z = -3.996
- Asymp. Sig. (2-tailed) = 0.000

There is a significant difference between the scientific reasoning abilities (post-test scores) of the experimental class and the control class, with the experimental class demonstrating higher scientific reasoning abilities than the control class.

Based on the results of the Mann-Whitney U test on the post-test data for scientific reasoning ability, the mean rank for the experimental class was 34.88 and for the control class was 18.12, indicating that, in terms of rank, the experimental class's scientific reasoning ability was higher than that of the control class. Furthermore, the Asymp. Sig. (2-tailed) value was 0.000. Since this significance value is less than 0.05 (0.000 < 0.05), H0 is rejected and H1 is accepted. Thus, it can be concluded that there is a significant difference between the scientific reasoning abilities of the experimental class and the control class after the treatment was administered, with the experimental class demonstrating better scientific reasoning abilities than the control class.

DISCUSSION

The results of the data analysis show that the implementation of the Problem-Based Learning (PBL) model using an experimental method has a significant effect on improving the IPAS learning outcomes of fifth-grade elementary school students. This finding is supported by the average post-test learning achievement score of the experimental class (87.03), which was significantly higher

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than that of the control class (73.58), as well as the results of the Mann-Whitney U test, which showed a significance value of 0.000 ($p < 0.05$).

These findings align with the theory that learning should actively engage students in constructing their own knowledge (Supena & Dewi, 2020). In this study, the PBL model combined with the experimental method was able to create an active and meaningful learning environment for students. PBL begins with the presentation of a contextual problem that stimulates students' curiosity. This is consistent with the statement by Mas Darwati & Made Purana (2020) that PBL encourages students to develop independent and collaborative learning skills through authentic problem-solving.

This significant difference also indicates that conventional, teacher-centered learning models (lectures and assignments) are less effective in fostering deep understanding of IPAS material. Students in the control class tended to be passive and merely received information, resulting in suboptimal learning outcomes. In contrast, students in the experimental class became active participants in their learning, which directly led to improved conceptual mastery as measured by learning outcome tests. Thus, it can be concluded that the integration of PBL and experiments is an effective and significant strategy for improving student learning outcomes, in line with 21st-century learning objectives that emphasize active and meaningful learning (Humayra et al., 2025).

The results of the analysis also show that the implementation of the PBL model using the experimental method has a significant effect on improving students' scientific reasoning skills. This is evident from the very striking difference in mean scores between the experimental class (84.23) and the control class (64.50), as well as the results of the Mann-Whitney U test, which showed a significance value of 0.000 ($p < 0.05$). The Partial Eta Squared value in the MANOVA test, which reached 0.604, also indicates a substantial contribution of the learning model to the improvement of this ability.

The improvement in scientific reasoning skills in the experimental class was not coincidental. This was due to a learning design that intrinsically trains these aspects of scientific reasoning. In PBL, students are presented with problems that require higher-order thinking processes to solve. They must identify problems, formulate hypotheses, collect and analyze data, and draw conclusions. This process is at the core of scientific reasoning (Usman et al., 2020). Students are trained to provide logical arguments, distinguish between scientific and nonscientific arguments, and analyze cause-and-effect relationships—all of which are crucial aspects of scientific reasoning (Saadah et al., 2025).

The experimental method reinforces this process by giving students the opportunity to test their reasoning through direct evidence. In experimental activities, students learn to control variables, observe data, and draw conclusions based on empirical evidence. The steps in the experimental method—from defining a problem to communicating results (Wilani et al., 2025)—are closely aligned with the measured indicators of scientific reasoning, such as proportional reasoning, variable control, and hypothesis-deductive reasoning (Shilla et al., 2022). This activity also encourages students to think systematically and logically.

In contrast, in conventional learning, students' reasoning skills are not significantly honed. Students primarily receive information and memorize facts, making it difficult for them when asked to analyze problems or draw their own conclusions. These findings align with the views of Hadi et al. (2021), who state that scientific reasoning develops through interaction with the science learning strategies employed by teachers. PBL and the experimental method provide an environment rich in scientific thinking experiences, thereby significantly enhancing students' scientific reasoning abilities. This is an important foundation for students to face future challenges and become critical and creative citizens.

CONCLUSION

Based on the research findings and discussion outlined above, the following conclusions can be drawn:

1. The implementation of the Problem-Based Learning (PBL) model using an experimental method has a significant effect on improving the science learning outcomes of fifth-grade elementary school students. This is indicated by a significant difference in average learning outcomes between the experimental and control classes ($87.03 > 73.58$) as well as statistical test results showing a significance value of 0.000 ($p < 0.05$).
2. The implementation of the Problem-Based Learning (PBL) model using an experimental method also has a significant effect on improving the scientific reasoning skills of fifth-grade elementary school students. This is evidenced by the average scientific reasoning ability of the experimental class, which was significantly higher than that of the control class ($84.23 > 64.50$), and statistical test results showing a significance value of 0.000 ($p < 0.05$).

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3. Simultaneously, the Problem-Based Learning (PBL) model combined with the experimental method had a significant effect on students' learning outcomes and scientific reasoning skills, with a contribution of 60.4%, which falls into the "large" effect size category.

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