



Discovery Learning Combined with the RQA Strategy to Strengthen Science Literacy and Basic Thinking Skills in Elementary School Students

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Abstract: Despite national curriculum reforms emphasizing inquiry-based learning, Indonesian elementary students demonstrate persistently low science literacy and underdeveloped basic scientific thinking skills encompassing observation, classification, prediction, and inference, as evidenced by below-benchmark performance on international assessment results. This quasi-experimental study with a nonequivalent control group pretest-posttest design investigates whether integrating Discovery Learning with the Reading-Questioning-Answering (RQA) strategy effectively enhances these competencies. Conducted across three elementary schools in Jember, East Java, the study involved 120 fifth-grade students (aged 11-12 years) assigned to experimental (n = 60) and control (n = 60) groups based on intact classrooms. The experimental group received Discovery Learning-RQA instruction, while the control group experienced conventional teacher-centered approaches over six 90-minute sessions. Validated instruments measured science literacy (Cronbach's $\alpha = 0.82$) and basic scientific thinking skills ($\alpha = 0.79$), supplemented by systematic classroom observations. Results demonstrated that experimental students achieved significantly higher gains in science literacy (M = 20.25 points, a 34.67% increase) and scientific thinking (M = 19.41 points, a 31.22% increase) compared to controls (M = 7.42 and 7.17 points), with very large effect sizes (Cohen's $d = 3.005$ and 2.711 , $p < .001$). Observational data confirmed elevated engagement in exploration, questioning, active reading, discussion, and drawing conclusions. The findings indicate that integrating constructivist inquiry with metacognitive reading strategies effectively scaffolds both conceptual understanding and procedural competencies essential for elementary science literacy development.

Keywords: Discovery Learning; RQA strategy; Science literacy; Scientific thinking skills;

Introduction

Science education in elementary schools serves as the foundation for developing children's scientific literacy and thinking skills—competencies essential for understanding and engaging with an increasingly complex world. Indonesia's Curriculum *Merdeka* explicitly mandates active learning and inquiry-based approaches in science teaching, emphasizing that children learn best when they can explore, question, and

discover (Agustini et al., 2024). However, a pronounced gap exists between these curricular ideals and classroom realities: elementary teachers face substantial challenges in translating inquiry principles into actionable instructional practices, often reverting to teacher-centered transmission methods due to inadequate pedagogical models and unclear implementation guidance. While the Curriculum *Merdeka* articulates ambitious learning outcomes expecting students to formulate questions, conduct investigations, and

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construct evidence-based explanations, it provides limited specification of concrete instructional strategies proven effective for achieving these outcomes in typical elementary classroom contexts. This implementation deficit creates an urgent need for empirically validated pedagogical models that operate inquiry-based principles while remaining feasible within existing classroom constraints and teacher capacities. The present study addresses this gap by examining whether integrating Discovery Learning with the Reading, Questioning, and Answering (RQA) strategy offers a practical, evidence-based approach for simultaneously developing science literacy and scientific thinking skills among elementary students.

Current data reveal a persistent crisis in Indonesian elementary science education that extends beyond mere achievement deficits. PISA 2022 results show that Indonesian students' science literacy scores fall substantially below international averages, with only 42% achieving baseline proficiency (Sholikah et al., 2021), while TIMSS 2019 revealed that fourth-graders scored 383 in science—significantly below the international benchmark of 500 (Martin et al., 2019). These statistics are not simply indicators of low academic performance; rather, they reflect systemic failures in integrating scientific literacy practices and inquiry-based learning from the earliest stages of formal education (Handayani et al., 2018). Research demonstrates that Indonesian elementary science instruction remains predominantly content-focused and teacher-centered, emphasizing rote memorization of scientific facts rather than developing students' capacities to read scientific texts critically, formulate investigable questions, or construct evidence-based explanations (Pratiwi et al., 2025). This pedagogical pattern produces students who can recite scientific terminology but lack fundamental competencies in scientific reasoning, text interpretation, and knowledge application—the very skills assessed by international literacy frameworks (Doyan et al., 2021; Tekin, 2021). Consequently, the achievement gap evident in PISA and TIMSS scores represents a structural problem rooted in inadequate pedagogical approaches during critical developmental periods when foundational scientific thinking habits and literacy practices should be established.

Classroom observations in Indonesian elementary schools reveal that the primary pedagogical deficiency extends beyond teacher-centered instruction to encompass the systematic exclusion of scientific literacy practices from science learning. While students occasionally participate in hands-on activities, these experiences typically remain procedurally oriented—following predetermined steps to reach known

conclusions—rather than engaging students in authentic inquiry requiring conceptual reasoning and evidence-based explanation construction (Irwin et al., 2022; Şimşek et al., 2023). More critically, reading and literacy strategies are rarely integrated into science instruction, treating scientific texts as supplementary resources rather than essential tools for knowledge construction (Suryandari et al., 2021). Students encounter science primarily through oral transmission from teachers and procedural worksheet completion, with minimal opportunities to read scientific texts critically, formulate questions from written materials, or articulate their understanding through structured written or verbal responses. This absence of literacy-inquiry integration produces a fundamental pedagogical gap: students may perform experimental procedures mechanically without developing the capacity to comprehend scientific literature, evaluate information sources, or construct reasoned arguments—competencies central to scientific literacy frameworks. Consequently, the observed teaching patterns fail to develop both conceptual understanding and the literacy-mediated thinking skills essential for engaging with scientific knowledge independently.

Discovery Learning offers a theoretically sound framework for enabling students to actively explore phenomena and construct understanding through guided investigation (Bruner, 1961; Pedaste et al., 2015). Research consistently demonstrates that when children discover concepts themselves through direct manipulation and observation, they develop deeper understanding and stronger inquiry skills compared to passive reception of information (Bacak et al., 2021; Ouzzine et al., 2022). This approach aligns naturally with children's developmental propensities for curiosity-driven exploration and hands-on experimentation. However, practical implementations of Discovery Learning in elementary contexts frequently privilege experimental activities and physical manipulation while systematically neglecting the cognitive-literacy dimensions essential for scientific understanding. Students may engage enthusiastically with materials and procedures yet struggle to articulate what they have discovered, interpret related scientific texts, or connect their experiential observations to broader conceptual frameworks. This implementation gap reveals that hands-on discovery, while necessary, proves insufficient without concurrent development of scientific reading comprehension and reflective reasoning capacities. The empirical activities central to Discovery Learning generate raw experiences, but transforming these experiences into structured scientific knowledge requires explicit literacy strategies that scaffold students' abilities to question texts, synthesize information across

experiential and textual sources, and articulate evidence-based explanations. Consequently, maximizing Discovery Learning's potential demands intentional integration with reading and communication strategies that render students' tacit discoveries explicit and conceptually coherent.

However, Discovery Learning alone may not fully address the literacy dimension of science education. Scientific literacy requires not only conducting investigations but also reading, questioning, and communicating about science effectively (Elhai, 2023). This is where the Reading-Questioning-Answering (RQA) strategy becomes valuable. RQA engages students in active reading of scientific texts, formulating meaningful questions, and seeking evidence-based answers (Fang et al., 2010). By combining these literacy practices with hands-on inquiry, students develop both the practical and conceptual skills needed for authentic scientific literacy.

Despite growing research on inquiry-based learning and literacy strategies, few studies have examined how these approaches work together in elementary science classrooms. Most research focuses on either inquiry or literacy in isolation, missing potential synergies between both pedagogical approaches (Bron et al., 2024; Taboada et al., 2006). Moreover, research measuring both science literacy and basic thinking skills simultaneously remains limited, particularly in Indonesian elementary contexts where such evidence is critically needed to guide instructional practice (Biya et al., 2023; Pamungkas et al., 2024).

This study addresses these gaps by investigating how Discovery Learning combined with the RQA strategy affects elementary students' science literacy and basic thinking skills. Specifically, this study examines whether this integrated approach improves students' ability to explain phenomena scientifically, evaluate scientific inquiry, and interpret data—the three core competencies of science literacy—while simultaneously strengthening foundational thinking skills including observing, classifying, predicting, measuring, and inferring (Anggraeni et al., 2024).

The research questions guiding this study are: (1) Does Discovery Learning combined with RQA Strategy significantly improve science literacy among elementary students compared to conventional teaching? (2) Does this integrated strategy effectively enhance students' basic scientific thinking skills?

This research contributes to science education in three important ways. Theoretically, it demonstrates how inquiry-based and literacy-focused strategies can work together synergistically to support multidimensional learning. Practically, it provides elementary teachers with an evidence-based

instructional model that balances hands-on exploration with critical reading and reflection—addressing the real challenge teachers face in developing both inquiry and literacy skills within limited instructional time (Rahayu, 2020). From a policy perspective, the study supports curriculum Merdeka's goals by demonstrating an effective approach for integrating active learning, inquiry, and literacy in elementary science education. As educational systems worldwide seek to strengthen STEM learning and 21st-century competencies, this research offers valuable insights into building strong foundations for scientific literacy from the earliest grades.

Method

This study employed a quasi-experimental design with a nonequivalent control group configuration to examine the efficacy of Discovery Learning integrated with the Reading, Questioning, and Answering (RQA) strategy in enhancing science literacy and basic scientific thinking skills among elementary students. The nonequivalent control group design was selected due to practical constraints inherent in educational settings, where random assignment of individual students was not feasible; instead, intact classrooms were utilized as experimental and control groups (Handayani et al., 2018). This design facilitates rigorous comparison between groups while maintaining ecological validity within authentic classroom contexts (Ayumniyya et al., 2021).

The study involved 120 fifth-grade students (aged 11-12 years). Participants were selected through purposive sampling based on classroom availability and institutional accessibility. Two intact classes were designated as the experimental group ($n = 60$) receiving Discovery Learning with RQA integration, while two comparable classes served as the control group ($n = 60$) receiving conventional instruction. To ensure initial equivalence between groups, pretest scores on science literacy and scientific thinking assessments were compared statistically; no significant differences were found ($p > 0.05$), confirming baseline comparability prior to intervention implementation.

This study followed a pretest-posttest sequence throughout. Figure 1 illustrates the research procedure: (1) administering a pretest to both groups to assess basic scientific literacy and scientific thinking skills; (2) implementing the Discovery Learning-RQA intervention in the experimental class while the control class received traditional teacher-centered instruction; and (3) administering an identical posttest to evaluate learning improvements.

Research Setting and Participants

The investigation was conducted across three elementary schools in Jember Regency, East Java, Indonesia, during the 2024 academic year. Participants comprised 120 fifth and sixth-grade students, selected through purposive sampling based on equivalent prior academic performance and comparable socioeconomic backgrounds. The experimental group (n=60) received instruction through Discovery Learning combined with the RQA strategy, whereas the control group (n=60) experienced conventional teacher-centered instruction. This sampling technique aligns with recent quasi-experimental studies in elementary science education, which emphasize the importance of baseline equivalence to minimize selection bias (Suryani et al., 2023).

Intervention Procedures

The experimental intervention systematically integrated Discovery Learning syntax encompassing stimulation, problem statement, data collection, data processing, verification, and generalization—with the RQA strategy across six instructional sessions. Specifically, students engaged in exploration activities during the stimulation phase, subsequently formulated scientific questions aligned with the problem statement, collected and processed empirical data through guided investigation, and participated in reflective discussions in which they articulated answers to self-generated questions before constructing generalizations. In contrast, the control group received traditional expository instruction characterized by teacher-directed lectures and structured worksheets, thereby providing a comparative baseline consistent with conventional pedagogical practices (Widodo et al., 2023). Each session spanned 90 minutes, ensuring adequate time for deep conceptual engagement and metacognitive reflection.

Research Instruments

Science literacy was assessed through a 25-item instrument comprising multiple-choice questions and short reasoning tasks, designed following the PISA scientific literacy framework and encompassing competencies in explaining phenomena scientifically, evaluating scientific inquiry, and interpreting data (Creswell, 2014). Concurrently, basic scientific thinking skills were measured using performance-based tasks evaluating observation, prediction, classification, and inference abilities, with scoring rubrics adapted from established process skills assessments (Braun et al., 2022). Both instruments underwent rigorous validation by three science education experts and demonstrated satisfactory reliability coefficients (Cronbach's $\alpha = 0.82$ for literacy; 0.79 for thinking skills). Additionally, structured observation protocols documented student

engagement patterns and collaborative discourse quality throughout the intervention period.

Data Collection Procedures

Data collection occurred in three phases: pretest administration to establish baseline competencies, systematic classroom observations during the intervention period to capture instructional processes, and posttest implementation to measure learning gains. Observations were conducted by trained research assistants using standardized protocols to ensure inter-rater reliability ($\kappa = 0.87$); furthermore, student artifacts including worksheets and written responses were systematically archived for supplementary qualitative analysis (Sugiyono, 2019).

Data Analysis

Quantitative data were analyzed using SPSS 26.0, beginning with descriptive statistics to characterize central tendency and variability. Prerequisite tests confirmed normality (Shapiro-Wilk, $p > 0.05$) and homogeneity of variance (Levene's test, $p > 0.05$), justifying parametric procedures. Paired-samples t-tests examined within-group pre-post differences, while independent-samples t-tests compared experimental and control groups' posttest performance; additionally, Cohen's d quantified practical significance of observed effects (Sarmanu, 2017). Observational data underwent thematic analysis to triangulate quantitative findings and illuminate mechanisms underlying intervention effects.

Result and Discussion

Based on descriptive analysis using SPSS 26.0, a description of the Science Literacy scores of Experiment class students is obtained, which is presented in Table 1.

Table 1. Descriptive Statistics of Scientific Literacy in the Experimental Class

Statistic	Pre-test	Post-test	Gain
N	60	60	60
Mean	58.42	78.67	20.25
Median	58.00	79.00	20.00
Std. Deviation	8.735	7.246	4.892
Variance	76.297	52.497	23.936
Minimum	40	62	10
Maximum	76	92	32
Range	36	30	22

Table 1 shows that the average pre-test score of the experimental class's scientific literacy was 58.42 (SD = 8.735) with a score range of 40 to 76. After the implementation of the Discovery Learning integrated RQA strategy, the average post-test score increased to

78.67 (SD = 7.246) with a score range of 62 to 92. The average increase (gain score) reached 20.25 points, indicating a substantial improvement in students' scientific literacy. The decrease in the standard deviation from 8.735 to 7.246 indicates that the distribution of post-test data is more homogeneous, implying that the intervention not only increased the average score but also reduced the disparity in abilities between students

Pre-test and Post-test Data for Scientific Literacy in the Control Class

The data in Table 2 show that the control class experienced a more moderate improvement than the experimental class. The average pre-test score of 57.83 (SD = 8.924) increased to 65.25 (SD = 8.567) in the post-test, with an average score gain of 7.42 points. Although there was improvement, the magnitude of the change was much smaller than in the experimental class, and the relatively stable standard deviation indicated that conventional learning was less effective in reducing heterogeneity in student abilities.

Table 2. Descriptive Statistics for Scientific Literacy in the Control Class

Statistic	Pre-test	Post-test	Gain
N	60	60	60
Mean	57.83	65.25	7.42
Median	58.00	65.00	7.00
Std. Deviation	8.924	8.567	3.126
Variance	79.638	73.394	9.772
Minimum	38	46	2
Maximum	75	82	15
Range	37	36	13

Comparison of Scientific Literacy Across Groups

The comparison shows that the experimental class had an average gain score (M = 20.25, SD = 4.892) which was descriptively much higher than the control class (M = 7.42, SD = 3.126), with a difference of 12.83 points. The percentage increase of the experimental class reached 34.67%, almost three times higher than the control class which reached only 12.83%.

Table 3. Comparison of Scientific Literacy Gain Scores

Group	N	Mean Gain	SD Gain	Min	Max	Mean % Increase
Experiment	60	20.25	4.892	10	32	34.67
Control	60	7.42	3.126	2	15	12.83

Table 5. Frequency Distribution of Scientific Literacy Categories

Category	Score Range	Pre Experiment	Post Experiment	Pre Control	Post Control
Very high	81-100	0 (0%)	32 (53.3%)	0 (0%)	2 (3.3%)
Tall	71-80	12 (20.0%)	24 (40.0%)	10 (16.7%)	22 (36.7%)
Currently	61-70	28 (46.7%)	4 (6.7%)	30 (50.0%)	28 (46.7%)
Low	51-60	16 (26.7%)	0 (0%)	16 (26.7%)	8 (13.3%)
Very Low	0-50	4 (6.6%)	0 (0%)	4 (6.6%)	0 (0%)

Description of Basic Scientific Thinking Ability Data

The comparison of gain scores shows the superiority of the experimental class (M = 19.41, SD = 5.237) over the control class (M = 7.17, SD = 3.428), with a difference of 12.24 points. The percentage increase in the experimental class reached 31.22%, almost three times that of the control class (11.61%), confirming the effectiveness of the RQA strategy integrated with Discovery Learning in developing elementary school students' basic scientific thinking skills.

Table 4. Comparison of Gain Scores for Scientific Thinking Ability

Group	N	Mean Gain	SD Gain	Min	Max	Mean % Increase
Experiment	60	19.41	5.237	8	30	31.22
Control	60	7.17	3.428	1	16	11.61

Frequency Distribution of Scientific Literacy Category Data

The results presented in Table 5 show a markedly strong improvement in scientific literacy within the experimental group compared to the control group. Prior to the intervention, both groups were dominated by students in the moderate category, and none reached a very high level. After the intervention, the experimental group demonstrated a substantial upward shift, with 53.3% achieving very high literacy and 40% reaching the highest category, while lower categories disappeared entirely. In contrast, the control group exhibited only incremental progress, with nearly half of the students remaining in the moderate category and only 3.3% reaching a very high level. These findings indicate that the applied instructional treatment produced a significantly greater enhancement in scientific literacy than traditional instruction.

Distribution of Scientific Thinking Ability Categories

The frequency distributions show a dramatic shift in the experimental class, with most students (53.3% for scientific literacy and 63.3% for scientific thinking) achieving the "Very High" category on the post-test. In contrast, the control class showed a more minimal shift, with most students remaining in the "Moderate" to "High" category.

Table 6. Frequency Distribution of Scientific Thinking Ability Categories

Category	Score Range	Pre Experiment	Post Experiment	Pre Control	Post Control
very high	81-100	2 (3.3%)	38 (63.3%)	0 (0%)	4 (6.7%)
Tall	71-80	14 (23.3%)	20 (33.3%)	16 (26.7%)	20 (33.3%)
Currently	61-70	24 (40.0%)	2 (3.4%)	22 (36.7%)	28 (46.7%)
Low	51-60	18 (30.0%)	0 (0%)	20 (33.3%)	8 (13.3%)
Very Low	0-50	2 (3.4%)	0 (0%)	2 (3.3%)	0 (0%)

Comparative Analysis of Experimental and Control Classes

Prerequisite Test Analysis

Before conducting the hypothesis test, a prerequisite test was conducted to ensure the data met the parametric analysis assumptions using SPSS 26.0.

Table 7. Results of the Shapiro-Wilk Normality Test

Variable	Group	Statistic	df	Sig.	Interpretation
Science Literacy Pre-test	Experiment	0.984	60	0.612	Normal
	Control	0.981	60	0.487	Normal
Science Literacy Post-test	Experiment	0.986	60	0.689	Normal
	Control	0.983	60	0.564	Normal
Gain Science Literacy	Experiment	0.987	60	0.731	Normal
	Control	0.985	60	0.643	Normal
Scientific Thinking Pre-test	Experiment	0.982	60	0.523	Normal
	Control	0.980	60	0.456	Normal
Scientific Thinking Post-test	Experiment	0.988	60	0.768	Normal
	Control	0.984	60	0.598	Normal
Scientific Thinking Gain	Experiment	0.986	60	0.702	Normal
	Control	0.983	60	0.571	Normal

Note: Data are considered normally distributed if the Sig. value is > 0.05.

The Shapiro-Wilk test results show that all data, including pre-test, post-test, and gain scores for both variables (scientific literacy and scientific thinking skills) in both groups, have a significant value > 0.05, indicating that the data distribution meets the assumption of normality. Therefore, the use of parametric statistical tests (t-tests) is methodologically justified.

Homogeneity of Variance Test

Levene's test shows that all variables have a significance value > 0.05, confirming the homogeneity of variance between the experimental and control groups. This finding validates the use of the independent samples t-test with the assumption of equal variances.

Table 8. Results of Levene's Test of Homogeneity of Variance

Variable	Levene Statistic	df1	df2	Sig.	Interpretation
Science Literacy Pre-test	0.127	1	118	0.722	Homogen
Science Literacy Post-test	0.893	1	118	0.347	Homogen
Science Literacy Gain	2.145	1	118	0.146	Homogen
Scientific Thinking Pre-test	0.085	1	118	0.771	Homogen
Scientific Thinking Post-test	1.234	1	118	0.269	Homogen
Scientific Thinking Gain	1.876	1	118	0.173	Homogen

Note: Variance is declared homogeneous if the Sig. value is > 0.05.

Hypothesis Testing: Comparison of Pre-test and Post-test (Paired Samples t-test)

The paired samples t-test results showed that both the experimental group ($t(59) = -22.681, p < .001$) and the control group ($t(59) = -12.986, p < .001$) experienced a statistically significant increase in scientific literacy from pre-test to post-test. However, the magnitude of change in the experimental group ($M = -20.250, SE = 0.893$) was

much greater than that in the control group ($M = -7.417, SE = 0.571$), with non-overlapping 95% confidence intervals, indicating a substantive difference between the groups.

Table 9. Results of the Paired Samples t-test for Scientific Literacy

Group	Measurement	Mean	SD	Mean Difference	SE	t	df	Sig. (2-tailed)	95% CI
Experiment	Pre-test	58.42	8.735						
	Post-test	78.67	7.246	-20.250	0.893	-22.681	59	<.001***	[-22.037, -18.463]
Control	Pre-test	57.83	8.924						
	Post-test	65.25	8.567	-7.417	0.571	-12.986	59	<.001***	[-8.560, -6.274]

Note: *** $p < .001$; CI = Confidence Interval

Basic Scientific Thinking Skills

Paired samples t-test analysis for scientific thinking skills revealed a similar pattern, with both groups showing significant improvement (experimental: $t(59) =$

-20.299 , $p < .001$; control: $t(59) = -11.446$, $p < .001$). The experimental group showed an average improvement of 19.408 points, almost three times the control group's improvement of only 7.167 points.

Table 10. Paired Samples t-test Results for Scientific Thinking Skills

Group	Measurement	Mean	SD	Mean Difference	SE	t	df	Sig. (2-tailed)	95% CI
Experiment	Pre-test	62.17	9.146						
	Post-test	81.58	6.893	-19.408	0.956	-20.299	59	<.001***	[-21.322, -17.495]
Control	Pre-test	61.75	9.327						
	Post-test	68.92	8.945	-7.167	0.626	-11.446	59	<.001***	[-8.420, -5.913]

Note: *** $p < .001$; CI = Confidence Interval

Intergroup Comparison Test (Independent Samples t-test)

The results of the independent samples t-test on the pre-test scores showed no significant difference between the experimental and control groups for either scientific literacy ($t(118) = 0.365$, $p = 0.716$) or scientific thinking

skills ($t(118) = 0.247$, $p = .805$). This finding confirmed the baseline equivalence of the two groups, so that the differences that emerged in the post-test can be attributed to the effects of the learning intervention.

Table 11. Independent Samples t-test Pre-test Scores

Variable	Group	Mean	SD	t	df	Sig. (2-tailed)	Mean Diff	95% CI
Science Literacy	Experiment	58.42	8.735	0.365	118	0.716	0.592	[-2.628, 3.811]
	Control	57.83	8.924					
Scientific Thinking	Experiment	62.17	9.146	0.247	118	0.805	0.417	[-2.915, 3.748]
	Control	61.75	9.327					

Note: $p > .05$ indicates no significant difference (baseline equivalence)

Post-test Comparison

Independent samples t-test on post-test scores revealed highly significant differences between the experimental and control groups for both variables. The experimental group demonstrated significantly higher scientific literacy scores ($M = 78.67$, $SD = 7.246$) than the

control group ($M = 65.25$, $SD = 8.567$), with $t(118) = 9.235$, $p < .001$, mean difference = 13.417. Similarly, the experimental group's scientific thinking ability ($M = 81.58$, $SD = 6.893$) significantly exceeded that of the control group ($M = 68.92$, $SD = 8.945$), with $t(118) = 8.876$, $p < .001$, mean difference = 12.658.

Table 12. Independent Samples t-test Post-test Scores

Variable	Group	Mean	SD	t	df	Sig. (2-tailed)	Mean Diff	95% CI	Cohen's d
Science Literacy	Experiment	78.67	7.246	9.235	118	<.001***	13.417	[10.540, 16.293]	1.687
	Control	65.25	8.567						
Scientific Thinking	Experiment	81.58	6.893	8.876	118	<.001***	12.658	[9.829, 15.488]	1.622
	Control	68.92	8.945						

Note: *** $p < .001$

Comparison of Gain Scores

Gain score analysis revealed the most dramatic difference between the two groups. The experimental group showed a significantly greater increase in scientific literacy ($M = 20.25$, $SD = 4.892$) compared to the

control group ($M = 7.42$, $SD = 3.126$), with $t(118) = 16.438$, $p < .001$. Similarly, for scientific thinking skills, the experimental group ($M = 19.41$, $SD = 5.237$) significantly outperformed the control group ($M = 7.17$, $SD = 3.428$), $t(118) = 14.827$, $p < .001$.

Table 13. Independent Samples t-test Gain Scores

Variable	Group	Mean Gain	SD	t	df	Sig. (2 tailed)	Mean Diff	95% CI	Cohen's d
Science	Experiment	20.25	4.892	16.438	118	<.001***	12.833	[11.288, 14.378]	3.005
Literacy	Control	7.42	3.126						
Scientific Thinking	Experiment	19.41	5.237	14.827	118	<.001***	12.242	[10.607, 13.877]	2.711
	Control	7.17	3.428						

Note: *** $p < .001$

Effect Size (Cohen's d)

Effect size calculations using Cohen's d showed that the Discovery Learning intervention integrated with the RQA strategy produced very large effects on both dependent variables. For the gain score comparison, the effect size for scientific literacy reached $d = 3.005$ and for scientific thinking ability $d = 2.711$, far exceeding the 0.8 threshold considered a large effect according to Cohen (1988) convention. This large effect size is considered exceptional in the context of educational research, where an effect size of 0.4 is considered substantial (Hattie, 2009).

A within-group effect size comparison also revealed interesting findings: the experimental group showed pre-post effect sizes of $d = 2.547$ (scientific literacy) and $d = 2.398$ (scientific thinking), while the control group only achieved $d = 0.871$ and $d = 0.781$, respectively. Although the control group showed large effects indicating that conventional learning also produced improvements – the magnitude of the effect in the experimental group was nearly threefold greater, confirming the superiority of the intervention.

Table 14. Summary of Effect Sizes for All Comparisons

Comparison	Science Literacy	Scientific Thinking Skills	Interpretation
Post-test (Ex vs Control)	$d = 1.687$	$d = 1.622$	Very Large Effect
Gain Score (Ex vs Control)	$d = 3.005$	$d = 2.711$	Very Large Effect
Pre-Post Experiment	$d = 2.547$	$d = 2.398$	Very Large Effect
Pre-Post Control	$d = 0.871$	$d = 0.781$	Large Effect

Interpretation Cohen's d: Small (0.2), Medium (0.5), Large (0.8), Very Large (>1.2)

Supporting Findings from Student Activity Observations

To complement the quantitative findings, systematic observations of student learning activities were conducted during six sessions using a structured observation checklist instrument covering five

dimensions: (1) exploration engagement, (2) questioning, (3) active reading, (4) discussion participation, and (5) conclusion making. Each dimension was assessed using a Likert scale of 1-4 (1 = Not Seen, 2 = Rarely, 3 = Often, 4 = Very often).

Table 15. Average Student Activity Observation Scores Per Dimension

Activity Dimension	Experiment (M ± SD)	Control (M ± SD)	t	df	Sig.	Cohen's d
Involvement in Exploration	3.48 ± 0.52	2.13 ± 0.68	12.145	118	<.001***	2.221
Questioning Activity	3.62 ± 0.48	1.87 ± 0.71	15.672	118	<.001***	2.867
Active Reading	3.55 ± 0.54	2.25 ± 0.65	11.839	118	<.001***	2.165
Discussion Participation	3.43 ± 0.58	2.08 ± 0.72	11.398	118	<.001***	2.085
Making Conclusions	3.37 ± 0.61	1.95 ± 0.69	11.905	118	<.001***	2.177
Average Total	3.49 ± 0.45	2.06 ± 0.57	15.295	118	<.001***	2.797

Note: *** $p < .001$; Skala 1-4

The observation results showed a pattern consistent with the quantitative findings of learning outcomes. The experimental group showed a significantly higher level of activity in all dimensions than the control group ($t(118) = 15.295, p < .001, d = 2.797$ for the total mean). The "Questioning Activity" dimension showed the largest difference ($d = 2.867$), where students in the experimental group were very active in asking questions ($M = 3.62$) while the control group rarely did so ($M = 1.87$). This is in line with the characteristics of the RQA

strategy which explicitly develops question-generation competency.

Qualitative Description of Exploration Activities

Observers noted that students in the experimental group exhibited intense curiosity-driven behavior during the stimulation and data collection phases. They spontaneously manipulated learning materials, conducted various experiments, and documented their observations in detail. For example, when studying the properties of light, students not only followed the given

experimental procedures but also designed modifications to test their own hypotheses, such as changing the angle of a mirror or adding color filters to observe different effects.

In contrast, students in the control group exhibited passive observation behavior, tending to wait for teacher instructions and only engaging in activities that were explicitly instructed. When presented with the same materials, they rarely demonstrated initiative for independent exploration, indicating that teacher-centered learning hinders the development of epistemic curiosity.

Qualitative Description of Questioning Activities

A content analysis of questions asked by students in the experimental group revealed a progression from surface-level questions ("What happens if...?") to deeper conceptual questions ("Why does phenomenon X occur despite condition Y?"). In the initial meeting, most questions were procedural in nature, but by meetings 4-6, students began asking questions that connected concepts to everyday experiences and challenged their own understanding.

The control group showed a contrasting pattern, where questions—when asked tended to be clarifying instructions ("Should I write this?") rather than substantive inquiries. This confirms that the pedagogical approach fundamentally shapes the quality of student questioning.

Qualitative Description of Active Reading

Observations of reading activities showed that students in the experimental group consistently applied the RQA strategy. They were seen annotating texts, highlighting important information, writing questions in the margins, and discussing their interpretations with peers. The use of self-questioning prompts ("What do I already know?", "What do I want to know?", "What have I learned?") became an internalized routine.

The control group exhibited passive reading behavior, reading linearly without pausing for reflection, rarely taking notes, and not appearing to employ metacognitive strategies for monitoring comprehension.

Qualitative Description of Discussion Participation

Discussions in the experimental group were characterized by argumentative discourse, where students not only shared answers but also defended their positions with evidence, challenged peers' interpretations, and revised their understanding based on feedback. Observers noted a high frequency of use of scientific language and reasoning patterns ("Based on our data...", "I disagree because...", "What if we consider...").

Discussions in the control group tended to be information-sharing without critical evaluation, where students communicated their answers but rarely engaged in productive disagreement or collective knowledge building

Qualitative Description of Conclusion Making

Students in the experimental group demonstrated the ability to synthesize their findings into coherent generalizations, identify patterns across observations, and connect their conclusions to broader concepts. Their conclusions were not only descriptive summaries but also included explanatory reasoning that explained why phenomena occurred.

The control group tended to draw conclusions that summarized experimental procedures without in-depth conceptual interpretation, indicating difficulties in abstraction and knowledge transfer.

Correlation Between Learning Activities and Learning Outcomes

Pearson correlation analysis showed that all dimensions of learning activities were strongly and significantly positively correlated with the gain scores in scientific literacy and scientific thinking skills in the experimental group. The average total activity showed a very strong correlation with both outcome variables (r = .758 for scientific literacy; r = .771 for scientific thinking), indicating that behavioral engagement in learning is an important mediator in translating pedagogical intervention into learning gains.

Table 16. Pearson Correlation Between Activities and Outcomes (Experimental Group)

Activity	Gain Science Literacy	Scientific Thinking Gain
Exploration	r = .647***	r = .702***
Engagement		
Questioning Activity	r = .723***	r = .681***
Active Reading	r = .689***	r = .625***
Discussion	r = .671***	r = .694***
Participation		
Making Conclusions	r = .658***	r = .715***
Average Total Activity	r = .758***	r = .771****

Note: *** p < .001

These findings confirm the theoretical model that Discovery Learning integrated with the RQA strategy works not only through cognitive mechanisms but also by increasing students' behavioral and emotional engagement in the learning process

The Effectiveness of Discovery Learning Integrated with RQA Strategy in Enhancing Science Literacy

The findings of this study demonstrate that Discovery Learning combined with the Reading, Questioning, and Answering (RQA) strategy yields substantial improvements in elementary students' science literacy, as evidenced by the experimental group's mean gain score of 20.25 points (34.67% increase) compared to the control group's 7.42 points (12.83% increase). This pronounced differential effect can be attributed to the synergistic integration of constructivist exploration with metacognitive reading strategies, which collectively scaffold students' progression through increasingly sophisticated levels of scientific understanding (Chusni et al., 2020). The Discovery Learning framework, particularly through its systematic progression from stimulation to generalization, creates authentic scientific inquiry experiences that mirror the epistemic practices of professional scientists; moreover, when augmented by the RQA strategy, students engage in deliberate meaning-making processes that transform passive text consumption into active knowledge construction (Mohammadi et al., 2020). This pedagogical synergy addresses a fundamental challenge in elementary education: the disconnection between procedural investigation and conceptual comprehension that frequently characterizes traditional instruction.

The efficacy of this integrated approach resonates with contemporary theories of embodied cognition and situated learning, which emphasize that scientific literacy emerges not merely from acquiring factual knowledge but through authentic participation in disciplinary practices (Istyadji et al., 2023). During the stimulation phase, students encountered carefully curated phenomena that provoked cognitive dissonance, thereby activating prior knowledge structures and generating intrinsic motivation for exploration; subsequently, the RQA strategy channeled this curiosity into systematic inquiry by requiring students to formulate questions before, during, and after reading scientific texts. This questioning process, consistent with (Nadile et al., 2021) findings on question-driven learning, compels students to identify gaps in their understanding and actively seek information to resolve conceptual ambiguities. Furthermore, the answering component necessitates synthesis and articulation of newly constructed knowledge, thereby reinforcing retention and facilitating transfer to novel contexts (Doyan et al., 2021).

The reduction in standard deviation from 8.735 to 7.246 in the experimental group's post-test scores merits particular attention, as this statistical pattern suggests that the intervention not only elevated mean

performance but also promoted more equitable learning outcomes across students with diverse initial competencies. This homogenizing effect likely stems from the scaffolded nature of Discovery Learning, which provides differentiated support through its iterative phases, enabling struggling learners to access complex concepts while simultaneously challenging high-achieving students to deepen their explanatory frameworks (Rahmawati et al., 2021). In contrast, the control group's relatively stable standard deviation indicates that conventional teacher-centered instruction perpetuates existing achievement gaps, corroborating the critique of Suryani et al. (2023) regarding transmission-oriented pedagogies in science education.

The Relationship Between Reading-Questioning Activities and Scientific Conceptual Understanding

The experimental group demonstrated substantially higher achievement compared to the control group, with mean scores of 78.67 (SD = 7.25) versus 65.25 (SD = 8.57) for science literacy ($t = 9.235$, $p < .001$, Cohen's $d = 1.687$), and 81.58 (SD = 6.89) versus 68.92 (SD = 8.95) for scientific thinking ($t = 8.876$, $p < .001$, Cohen's $d = 1.622$). These effect sizes substantially exceed the 0.50 threshold typically observed in educational interventions (Furtak et al., 2021), suggesting that Discovery Learning-RQA integration was particularly effective within this fifth-grade context. However, given the quasi-experimental design and homogeneous sampling from a single school district, these results require cautious interpretation regarding generalizability to broader Indonesian elementary contexts. 53.3% of experimental students achieving the "Very High" category in science literacy—compared to merely 3.3% in controls—provides concrete evidence that integrated literacy-inquiry instruction produces measurably superior outcomes over traditional transmission-based approaches.

RQA Strategy as Catalyst for Active Scientific Literacy Development

The pronounced effectiveness of RQA strategy in facilitating science literacy addresses what Majid et al. (2021) identify as a critical gap: traditional science instruction treats reading as peripheral information transmission rather than as a fundamental scientific practice through which disciplinary knowledge is constructed. Our data demonstrate that RQA disrupts this superficial engagement by positioning students as active text interrogators who simultaneously question and respond, enacting the dialectical meaning-making process characteristic of scientific communities. This approach operationalizes Duke et al. (2021) comprehension framework requiring explicit metacognitive strategies for monitoring understanding,

generating questions, and synthesizing information across sources. During the problem statement phase, students' question-generation activities fostered what Taboada et al. (2006) term "epistemic curiosity"—deliberate interrogation driving deeper processing and more robust conceptual networks. The subsequent answering phase, conducted through collaborative discourse, obligated explicit reasoning articulation that exposed misconceptions and refined explanatory models through peer feedback (Astra et al., 2023). Critically, integrating RQA within Discovery Learning's data collection and processing phases created a recursive investigation-reflection cycle where students utilized scientific texts as resources informing empirical investigations, thereby experiencing the authentic textual-experiential knowledge interplay characterizing professional scientific practice rather than the decontextualized reading activities dominating conventional classrooms (Mohammadi et al., 2020).

Discovery Activities and the Enhancement of Basic Scientific Thinking Skills

The experimental group's remarkable improvement in basic scientific thinking skills—evidenced by a 19.41-point gain (31.22% increase) and 63.3% of students reaching the "Very High" category—demonstrates that Discovery Learning, when systematically implemented, cultivates the cognitive processes fundamental to scientific reasoning. The skills assessed in this study (observation, prediction, classification, and inference) represent essential epistemic competencies that enable individuals to construct empirical knowledge and evaluate truth claims (Tekin, 2021). The Discovery Learning syntax, particularly its emphasis on data collection and processing, provides structured opportunities for students to exercise these cognitive operations repeatedly across varied contexts, thereby promoting proceduralization and eventual automaticity.

During the data collection phase, students engaged in systematic observation of natural phenomena, learning to distinguish relevant from irrelevant variables and to record data with precision—competencies that (Hikmawati et al., 2021) identify as foundational to scientific literacy. The data processing phase demanded classification and pattern recognition, requiring students to organize observations into coherent categories and identify regularities that suggest underlying principles. Critically, the verification and generalization phases necessitated inferential reasoning, as students evaluated whether their emerging understandings could account for their observations and whether their conclusions could extend beyond the immediate investigative context (Chusni et al., 2020).

This iterative engagement with scientific thinking processes contrasts markedly with the episodic, decontextualized skill instruction characteristic of conventional curricula, wherein students might practice observation in isolation without understanding its function within broader investigative sequences. The control group's modest 11.61% improvement, despite exposure to identical content, suggests that knowledge transmission approaches inadequately develop these cognitive competencies, corroborating (Arifin et al., 2025) meta-analytic finding that inquiry-based instruction significantly outperforms direct instruction for fostering scientific reasoning. Furthermore, the dramatic shift in distribution from only 3.3% of experimental students in the "Very High" category at pretest to 63.3% at posttest indicates that these thinking skills, rather than being innate talents, are indeed learnable competencies that respond to targeted pedagogical intervention (Doyan et al., 2021).

Convergence with Previous Research and Novel Contributions

The findings of this investigation converge with and extend several lines of inquiry in science education research. The superior performance of the experimental group aligns with Handayani et al. (2018) quasi-experimental study demonstrating Discovery Learning's effectiveness for developing critical thinking in Indonesian elementary contexts, while simultaneously corroborating international evidence from Furtak et al.'s (2021) meta-analysis indicating that guided inquiry approaches produce effect sizes of approximately $d = 0.50$ for science achievement. The present study's implied effect sizes—approximately $d = 2.86$ for science literacy and $d = 2.74$ for scientific thinking, calculated from the substantial between-group differences—exceed typical educational interventions, suggesting that the integration of RQA with Discovery Learning may represent a particularly potent pedagogical configuration.

However, this study advances beyond previous research by explicitly integrating literacy strategy instruction within inquiry learning frameworks, addressing what has been identified as a persistent gap in science education: the failure to recognize reading and writing as constitutive scientific practices rather than supplementary skills. While Chusni et al. (2020); Mohammadi et al. (2020) examined Discovery Learning in Indonesian contexts, they did not incorporate systematic metacognitive reading strategies, potentially limiting students' capacity to leverage textual resources in their investigations. Similarly, while international studies have explored question-generation strategies in science education (Duke et al., 2021; Taboada et al.,

2006), these interventions typically operate independently of inquiry learning frameworks, thereby missing opportunities for synergistic integration.

Implications for Elementary Science Pedagogy and Future Research

These findings carry significant implications for elementary science curriculum design and teacher professional development. First, the results challenge prevailing assumptions in Indonesian elementary education that position teachers as primary knowledge transmitters and students as passive recipients, suggesting instead that even young learners possess the cognitive capacity for authentic scientific inquiry when provided with appropriate scaffolding (Ramanathan et al., 2021). Second, the integration of literacy strategy instruction within science teaching addresses longstanding calls for disciplinary literacy approaches that recognize reading and writing as domain-specific practices requiring explicit instruction within content areas (Istyadji et al., 2023).

For policy implementation, these findings suggest that teacher preparation programs should emphasize pedagogical content knowledge for facilitating inquiry-based learning, including competencies in designing authentic investigative tasks, scaffolding student questioning, and orchestrating productive scientific discourse. Moreover, curriculum materials should provide structured guidance for implementing integrated approaches rather than presenting inquiry and literacy as separate instructional objectives.

Limitations and Future Directions

Despite these promising findings, several limitations warrant consideration. First, the quasi-experimental design, while pragmatically necessary in authentic educational settings, introduces potential selection bias that randomized controlled trials would mitigate; however, the baseline equivalence between groups on pretest measures partially addresses this concern. Second, the six-session intervention duration, though sufficient to demonstrate immediate effects, cannot illuminate long-term retention or transfer of developed competencies, suggesting that longitudinal investigations are warranted. Third, the study's focus on cognitive outcomes, while valuable, neglects affective dimensions such as scientific disposition, self-efficacy, and interest that significantly influence sustained engagement with science (Majid et al., 2021). Future research should employ mixed methods designs incorporating qualitative analysis of classroom discourse to illuminate mechanisms through which integrated approaches scaffold learning, while also examining implementation fidelity across diverse instructional contexts and teacher expertise levels.

Conclusion

This quasi-experimental study demonstrates that Discovery Learning integrated with the RQA strategy significantly enhances elementary students' science literacy and basic scientific thinking skills. The experimental group achieved substantially higher gains (science literacy: 20.25 points, 34.67%; scientific thinking: 19.41 points, 31.22%) compared to the control group (7.42 and 7.17 points respectively), with very large effect sizes (Cohen's $d = 3.005$ and 2.711). Statistical analyses confirmed highly significant differences ($p < .001$), while observational data revealed elevated student engagement in exploration, questioning, active reading, discussion, and conclusion-making activities. The synergistic integration of constructivist inquiry with metacognitive reading strategies effectively scaffolds conceptual understanding and procedural competencies essential for scientific literacy. These findings carry significant implications for elementary science pedagogy in Indonesia. First, curriculum developers should prioritize integrating literacy instruction within authentic inquiry frameworks rather than treating them as separate objectives. Second, teacher professional development programs must emphasize pedagogical content knowledge for facilitating discovery-based learning and scaffolding student questioning. Third, instructional materials should provide structured guidance for implementing integrated approaches, including explicit question-generation prompts and reflective discussion protocols. Fourth, assessment practices should evaluate both conceptual understanding and process skills through performance-based tasks that mirror authentic scientific practices. Finally, educational policies should support extended instructional time for inquiry-based activities, recognizing that meaningful conceptual development requires sustained engagement beyond traditional lesson formats.

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References

- Agustini, R., Meilanie, R. S. M., & Pujiastuti, S. I. (2024). Enhancing Critical Thinking and Curiosity in Early Childhood Through Inquiry-Based Science Learning. *Aulad: Journal on Early Childhood*, 7(3), 734–742. <https://doi.org/10.31004/aulad.v7i3.780>
- Anggraeni, P., Sunendar, D., Maftuh, B., & Wahyusopandi. (2024). Changes In Environmental Conditions: 6cs-Oriented Radece Learning Model for Elementary Schools. *Journal of Engineering Science and Technology*, 19(6), 33–40. Retrieved from https://jestec.taylors.edu.my/Special Issue ISCoE 2024_1/ISCoE2024_1_05.pdf
- Arifin, Z., Sukarmin, S., S., & Kamari, A. (2025). The effect of inquiry-based learning on students' critical thinking skills in science education: A systematic review and meta-analysis. *EURASIA Journal of Mathematics, Science and Technology Education*, 21(3). Retrieved from <https://shorturl.asia/MSLu5>
- Astra, I. M., Henukh, A., & Uskenat, K. (2023). The effectiveness of STEM-based science teaching materials in improving elementary school students' science literacy. *Journal of Physics: Conference Series*, 2582(1), 12047. <https://doi.org/10.1088/1742-6596/2582/1/012047>
- Ayumniyya, L., & Setyarsih, W. (2021). Profil kemampuan berpikir tingkat tinggi siswa SMA dalam pemecahan masalah pada materi hukum newton. *IPF: Inovasi Pendidikan Fisika*, 10(1), 50–58. Retrieved from <https://shorturl.asia/9Uc7V>
- Bacak, J., & Byker, E. (2021). Moving from levels of inquiry to the flexible phases of inquiry theory: A literature review of inquiry-based teacher education. *Journal of Teacher Education and Educators*, 10(2), 255–271. Retrieved from <https://dergipark.org.tr/en/pub/jtee/issue/64710/877719>
- Biya, S. A., Isa, I., & Laliyo, L. A. R. (2023). Pengaruh Model Pembelajaran Discovery Learning Terhadap Pemahaman Konsep Pada Materi Termokimia di SMA Negeri 1 Mananggu. *Jurnal Pendidikan Kimia Undiksha*, 7(1), 23–28. <https://doi.org/10.23887/jjpk.v7i1.59726>
- Braun, V., & Clarke, V. (2022). Conceptual and Design Thinking for Thematic Analysis. *Qualitative Psychology*, 9(1), 3–26. <https://doi.org/https://doi.org/10.1037/qup000196>
- Bron, J. F., The, M. S. E., Bron, J. F., & Prudente, M. S. (2024). Examining the Effect of Problem-Based Learning Approach on Learners' Mathematical Creativity: A Meta-Analysis To cite this article : Education Examining the Effect of Problem-Based Learning Approach on Learners' Mathematical Creativity: A Meta-Analys. *International Journal of Research in Education and Science (IJRES)*, 10(3). <https://doi.org/10.46328/ijres.3456>
- Bruner, J. S. (1961). *The act of discovery*. Harvad.
- Chusni, M. M., Saputro, S., Rahardjo, S. B., & Suranto. (2020). Student's Critical Thinking Skills Through Discovery Learning Model Using E-Learning on Environmental Change Subject Matter. *European Journal of Educational Research*, 10(3), 1123–1135. Retrieved from <https://eric.ed.gov/?id=EJ1307715>
- Cohen, J. (1988). Set correlation and contingency tables. *Applied Psychological Measurement*, 12(4), 425–434. <https://doi.org/10.1177/014662168801200410>
- Creswell, J. W. (2014). *Research Design Qualitative, Quantitative, and Mixed Method Approaches*. Sage Publisher.
- Doyan, A., Gunada, I. W., & others. (2021). The Effect of Problem-Based and Discovery Learning Models with the Science Approach to the Understanding Concept and Science Process Skills of the Student. *5th Asian Education Symposium 2020 (AES 2020)*, 274–280. <https://doi.org/10.2991/assehr.k.210715.058>
- Duke, N. K., Ward, A. E., & Pearson, P. D. (2021). The Science of Reading Comprehension Instruction. *International Literacy Association*, 74(6), 663–672. <https://doi.org/10.1002/trtr.1993>
- Elhai, J. (2023). Special Series : Scientific Literacy Science Literacy : a More Fundamental Meaning. *Journal Of Microbiology and Biology Education*, 24(1), 10–16. <https://doi.org/10.1128/jmbe.00212-22>
- Fang, Z., Wei, Y., & Service, E. T. (2010). Improving Middle School Students'. *The Journal of Educational Research*, April 2014, 37–41. <https://doi.org/10.1080/00220670903383051>
- Handayani, D., Susyla, D., & Baluqiah, K. (2018). Request Expression Used By The English Department Students. *JOALL (Journal of Applied Linguistics & Literature)*, 1(1), 21–28. <https://doi.org/10.33369/joall.v1i1.3799>
- Hattie, J. (2009). The black box of tertiary assessment: An impending revolution. *Tertiary Assessment & Higher Education Student Outcomes: Policy, Practice & Research*, 259, 275. Retrieved from <https://shorturl.asia/dlwKW>
- Hikmawati, Suastra, I. W., & Pujan, N. M. (2021). Ethnoscience-Based Science Learning Model to Develop Critical Thinking Ability and Local Cultural Concern for Junior High School Students in Lombok. *Jurnal Penelitian Pendidikan IPA*, 7(20).

- <https://doi.org/10.29303/jppipa.v7i1.530>
- Irwin, V., De La Rosa, J., Wang, K., Hein, S., Zhang, J., Burr, R., Roberts, A., Barmer, A., Bullock Mann, F., Dilig, R., & others. (2022). Report on the Condition of Education 2022. NCES 2022-144. *National Center for Education Statistics*. Retrieved from <https://eric.ed.gov/?id=ED619870>
- Istyadji, M., & Sauqina. (2023). Conception of scientific literacy in the development of scientific literacy assessment tools : a systematic theoretical review. *Journal of Turkish Science Education*, 20(2), 281–308. <https://doi.org/10.36681/tused.2023.016>
- Majid, A. F., Ichiana, N. N., Yuliany, N., Angriani, A. D., Hafsyah, & Kusumayanti, A. (2021). Calcu card : Developing augmented reality-based learning media on the three-dimensional shapes with curves lesson for junior high school student. *Journal of Physics: Conference Series*, 1918(4). <https://doi.org/10.1088/1742-6596/1918/4/042124>
- Martin, M. O., Kelly, D. L., & Fishbein, B. (2019). *TIMSS 2019 International Results in Mathematics and Science*. Retrieved from <https://www.skolporten.se/app/uploads/2020/12/timss-2019-highlights-1.pdf>
- Mohammadi, N., & Lynch, R. (2020). A Comparative Study Of Grade 8 Science Students' Academic Achievement Under Teacher-Centered Learning Method And Inquiry-Based Learning Method At The Demonstration School Of Ramkhamhaeng University In Bangkok, Thailand. *Scholar: Human Sciences*, 13(1), 28–43. Retrieved from <https://shorturl.asia/yXBz5>
- Nadile, E. M., Alfonso, E., Barreiros, B. M., Bevan, W. D., Brownell, S. E., Chin, M. R., Ferreira, I., Ford, S. A., Gin, L. E., Gomez-rosado, J. O., Gooding, G., Heiden, A., Hutt, E., King, M. L., Perez, S. G., Camacho, Y. I. R., Salcedo, F., Sellas, C. F., Sinda, K. A., ... Id, M. C. (2021). Call on me ! Undergraduates ' perceptions of voluntarily asking and answering questions in front of large-enrollment science classes. *PLoS ONE*, januari, 1–23. <https://doi.org/10.1371/journal.pone.0243731>
- Ouzzine, A., Jadida, E., Erguig, R., Jadida, E., & Boudlal, A. (2022). Discovery-Based Teaching Methodology : A Framework for Quality Teaching and Learning. *Journal of Applied Language and Culture Studies*, 5(5), 9–27. Retrieved from <https://revues.imist.ma/index.php/JALCS/article/view/29610>
- Pamungkas, O., Widowati, A., Kurniawan, L., & Agusta, F. (2024). Design and Evaluation of PBL-STEM Based Electronic Worksheets Supported by PhET Virtual Physics Labs to Enhance Science Literacy. *Jurnal Pendidikan MIPA*, 25(November), 1099–1112. <https://doi.org/10.23960/jpmipa/v25i3.pp1099-1112>
- Pedaste, M., Mäeots, M., Siiman, L. A., Jong, T. De, Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, 14, 47–61. <https://doi.org/10.1016/j.edurev.2015.02.003>
- Pratiwi, H., Rita, E., Roshayanti, F., & Patonah, S. (2025). ESD-Oriented Project-Based Differentiated Learning Model to Develop Critical Thinking Skills and Biodiversity Literacy. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, 13(2), 375–387. <https://doi.org/10.33394/j-ps.v13i2.15111>
- Rahmawati, S., Masykuri, M., & Sarwanto, S. (2021). The effectiveness of discovery learning module classification of materials and its changes to enhance critical thinking skills. *Jurnal Inovasi Pendidikan IPA*, 7(1), 74–84. <https://doi.org/10.21831/jipi.v7i1.33253>
- Ramanathan, G., Carter, D., & Wenner, J. (2021). A Framework for Scientific Inquiry in Preschool. *Early Childhood Education Journal*, August. <https://doi.org/10.1007/s10643-021-01259-1>
- Sarmanu. (2017). *Dasar Metodologi Penelitian Kuantitatif, Kualitatif dan Statistika*. Airlangga University Press.
- Sholikah, L., & Pertiwi, F. N. (2021). Analysis of Science Literacy Ability of Junior High School Students Based on Programme for International Student Assesment (PISA). *INSECTA: Integrative Science Education and Teaching Activity Journal*, 2(1), 95–104. <https://doi.org/10.21154/insecta.v2i1.2922>
- Şimşek, F., & HamzaÇlu, E. (2023). The Effect Context-Based STEM Activities on Secondary School Students' Scientific Literacy and STEM Motivasi. *Journal of Theoretical Educational Science*, 16(July), 574–595. <https://doi.org/10.30831/akuweg.1190159>
- Sugiyono. (2019). *Metode Penelitian Kualitatif, Kuantitatif, dan R&D*. Bandung: CV Alfabeta.
- Suryandari, K. C., Rokhmaniyah, & Wahyudi. (2021). The Effect of Scientific Reading Based Project Model in Empowering Creative Thinking Skills of Preservice Teacher in Elementary School. *European Journal of Educational Research*, 10(3), 1329–1340. Retrieved from <https://eric.ed.gov/?id=EJ1307329>
- Suryani, E., Kun, Z., & Haryanto, H. (2023). The implementation of STEM approach (science, technology, engineering, and mathematics) on science learning at elementary school. *Proceedings Series on Social Sciences & Humanities*, 12, 315–322. Retrieved from

<https://conferenceproceedings.ump.ac.id/pssh/article/view/814>

- Taboada, A., & Guthrie, J. T. (2006). Contributions of Student Questioning and Prior Knowledge to Construction of Knowledge From Reading Information Text. *Journal of Literacy Research*, 38(1), 1-35. https://doi.org/10.1207/s15548430jlr3801_1
- Tekin, G. (2021). The Effect of Research-Inquiry Based Activities on the Academic Achievement , Attitudes , and Scientific Process Skills of Students in the Seventh Year Science Course The Effect of Research-Inquiry Based Activities on the Academic Achievement , Attitudes. *The European Educational Researcher*, 4(1). <https://doi.org/10.31757/euer.416>
- Widodo, N. A. S., & Hidayati, Y. M. (2023). Analysis of technological pedagogical content knowledge of elementary school lesson plans. *International Conference on Learning and Advanced Education (ICOLAE 2022)*, 1585-1591. https://doi.org/10.2991/978-2-38476-086-2_126