
Improving Students' Scientific Reasoning through Discovery Learning in Elementary Science Instruction

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Abstract

Scientific reasoning is an essential competency in elementary science education, yet many students show limited ability to analyze evidence, formulate hypotheses, and draw logical conclusions due to teacher-centered instruction. This classroom action research aimed to improve students' scientific reasoning through the implementation of the Discovery Learning model. The study involved 28 fourth-grade students at SD Amaliah and was conducted in three cycles consisting of planning, action, observation, and reflection. Data were collected through scientific reasoning tests, observations, and field notes, then analyzed descriptively. The results showed a significant improvement in students' scientific reasoning, with average scores increasing from 56.8 in the pre-action stage to 87.4 in Cycle III, while learning mastery improved from 36% to 92%. These findings indicate that Discovery Learning effectively enhances scientific reasoning by encouraging active inquiry and evidence-based problem-solving. It can be concluded that Discovery Learning is an effective instructional model for elementary science learning.

Keywords

Discovery Learning; Elementary Education; Science Education; Scientific Reasoning.



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INTRODUCTION

Scientific reasoning is one of the fundamental competencies that students need to develop in order to meet the challenges of the twenty-first century. Amid the rapid advancement of science and technology, students are no longer expected merely to acquire factual knowledge; they are also required to analyze information, evaluate evidence, and draw logical conclusions based on empirical data (Bhaw et al, 2023; manel & Hendra, 2023; Benhorin, 2023). In the context of elementary education, strengthening scientific reasoning is particularly essential, as this stage marks the beginning of students' development of systematic thinking structures that serve as the foundation for subsequent science learning. Therefore, science instruction in elementary

schools should be designed to provide learning experiences that encourage active exploration, investigation, and conceptual discovery.

The urgency of developing scientific reasoning skills is also aligned with national educational policy directions. Law Number 20 of 2003 concerning the National Education System emphasizes that education aims to develop learners' potential to become competent, creative, independent individuals capable of rational thinking (Zhang *et al*, 2019; Convertini, 2021; Tofel & Ball, 2022). Furthermore, national educational policies highlight the importance of active, student-centered learning as a means of fostering higher-order thinking skills. In science education, these policy directions require teachers to implement instructional strategies that not only transmit scientific concepts but also facilitate students' scientific thinking processes through observation, analysis, and reflection (Gattinoni *et al*, 2020; Oesterhaus & Koerber, 2023; Krell *et al*, 2023). Nevertheless, numerous studies indicate that elementary school students' scientific reasoning abilities remain below optimal levels. Several studies have reported that students frequently encounter difficulties in formulating hypotheses, connecting evidence to scientific concepts, and drawing consistent conclusions based on observational findings (Vasen *et al*, 2021; Geourgeu, 2022; Coleman *et al*, 2023). This condition is often associated with instructional practices that remain largely focused on rote memorization and teacher-dominated classroom interactions. Excessively teacher-centered approaches limit students' opportunities to develop analytical thinking processes through direct learning experiences.

Within the science education literature, differing perspectives exist regarding the most effective instructional strategies for fostering scientific reasoning among elementary school students. Some scholars argue that inquiry-based approaches such as discovery learning are effective because they provide students with opportunities to construct knowledge independently through structured exploration. This approach is believed to enhance analytical thinking, problem-solving skills, and evidence-based reasoning. However, other perspectives suggest that minimally guided discovery learning may impose excessive cognitive load on elementary school students, who are generally at the concrete operational stage of cognitive development. Consequently, adequate scaffolding is considered necessary to ensure that the discovery process is effective. This debate indicates that the effectiveness of discovery learning depends substantially on the quality of its implementation and the specific learning context.

The discovery learning model itself is grounded in constructivist theory, which positions learners as active constructors of knowledge through interaction with their learning environment. In practice, this model involves several stages, including stimulation, problem identification, data collection, data processing, verification, and generalization. Conceptually, this structure is highly relevant to scientific reasoning indicators, as it encourages students to observe phenomena, formulate hypotheses, test information, and draw conclusions based on evidence. Previous studies have demonstrated that discovery learning contributes positively to science achievement, critical thinking skills, and science process skills. However, studies specifically examining the enhancement of elementary students' scientific reasoning through the implementation of this model remain relatively limited, particularly within the context of

elementary science education in Indonesia. Preliminary classroom observations revealed that students still experience difficulties in explaining scientific phenomena logically, posing investigative questions, and relating observational findings to the concepts being studied. Most students tend to provide brief responses without sufficient scientific argumentation (Fabre *et al*, 2023). This condition indicates the need for instructional innovation capable of fostering deeper cognitive engagement among students.

Based on the gap between curricular demands, empirical findings, and classroom learning needs, this study aims to enhance students' scientific reasoning through the implementation of the discovery learning model in elementary science instruction. The study was conducted using a classroom action research approach as a systematic effort to directly improve instructional practices. This research is significant because it is expected to provide empirical evidence regarding the effectiveness of discovery learning implementation in fostering elementary students' scientific reasoning (Tabak & Dubovi, 2023; Malone & schuchuldt, 2023). Specifically, this study concludes that the structured implementation of the discovery learning model has the potential to increase students' active engagement, strengthen evidence-based analytical skills, and promote the enhancement of scientific reasoning in science learning. The findings are expected to contribute conceptually to the development of elementary science education and serve as a practical reference for teachers in designing more meaningful learning experiences aligned with the demands of twenty-first-century education.

METHODS

This study employed a classroom action research (CAR) approach aimed at improving the science learning process through the implementation of the discovery learning model to enhance elementary school students' scientific reasoning. This approach was selected because it enables systematic, reflective, and continuous improvements in classroom instructional practices. The research design was based on the classroom action research model proposed by Stephen Kemmis and Robin McTaggart (2022), which consists of cyclical stages including planning, acting, observing, and reflecting. The study was conducted over three cycles, with each cycle consisting of two learning sessions. The research participants were 28 fourth-grade students of SD Amaliah, comprising 14 male and 14 female students.

This study aimed to analyze the improvement in students' scientific reasoning abilities following the implementation of the discovery learning model in science instruction in 2025. Scientific reasoning in this study was assessed through several indicators, including the ability to identify problems, formulate hypotheses, collect and interpret data, connect evidence with scientific concepts, and draw logical conclusions based on observational findings. The instructional intervention focused on the stages of the discovery learning model, namely stimulation, problem identification, data collection, data processing, verification, and generalization. Each stage was specifically designed to provide students with opportunities to develop analytical and evidence-based thinking processes.

Data were collected through observation, tests, documentation, and field notes. Observation was conducted to obtain data regarding student activities and the implementation of the instructional process during the intervention. Tests were administered at the end of each cycle to measure the development of students' scientific reasoning abilities (Saphia *et al*, 2022; Choowong & Worapun, 2021; Lazonder & Janssen, 2021). The test instrument consisted of essay-based questions designed according to the scientific reasoning indicators. Documentation, including photographs of classroom activities and students' work, was used as supporting data. Field notes were employed to record various findings during the implementation process, including students' responses to the applied instructional model. Quantitative data were analyzed using descriptive comparative analysis by comparing students' scientific reasoning test results across cycles. The percentage of learning mastery was calculated to determine students' achievement levels at each stage of the intervention (Sahin & Sasmaz, 2022). Meanwhile, qualitative data obtained from observations and field notes were analyzed through the stages of data reduction, data display, and conclusion drawing. The intervention was considered successful if at least 80% of students achieved the predetermined mastery criteria and demonstrated improvement across the scientific reasoning indicators.

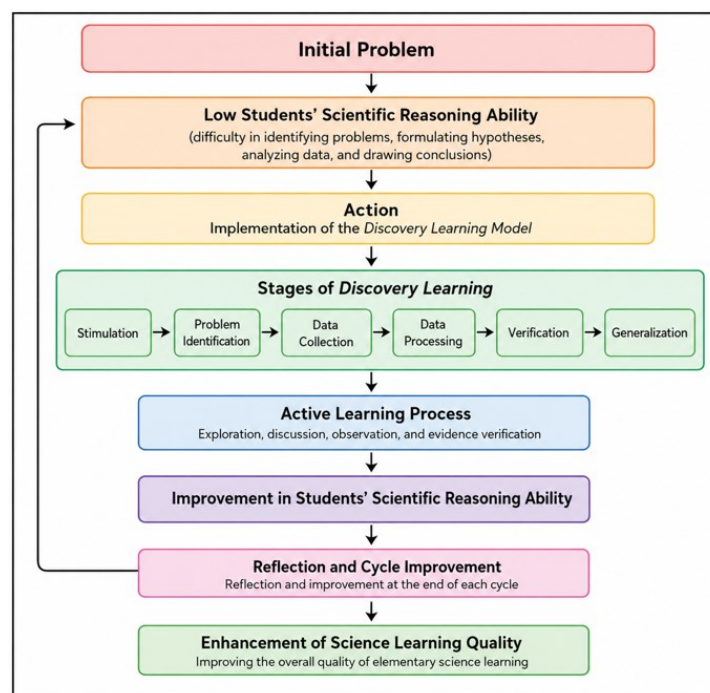


Figure 1. Research Activity Flowchart

Figure 1 illustrates the classroom action research framework, which began with the identification of the initial problem, namely students' low scientific reasoning abilities, as reflected in their difficulties in identifying problems, formulating hypotheses, analyzing data, and drawing conclusions. To address this issue, an intervention was implemented through the systematic application of the Discovery Learning model, encompassing the stages of stimulation, problem identification, data collection, data processing, verification, and generalization. Each stage promoted active learning processes through exploration, discussion,

observation, and evidence-based verification, thereby enabling students to engage directly in the process of independently constructing concepts. This active engagement contributed to the improvement of students' scientific reasoning abilities. Furthermore, the outcomes of each intervention were evaluated through reflection and continuous refinement at the end of every cycle to optimize the instructional process, ultimately leading to the overall enhancement of science learning quality.

FINDINGS AND DISCUSSION

Findings

This classroom action research was conducted over three cycles with the objective of enhancing students' scientific reasoning through the implementation of the discovery learning model in elementary science instruction. Each cycle consisted of the stages of planning, action implementation, observation, and reflection. The research findings were analyzed based on the development of students' scientific reasoning abilities as measured through tests administered at the end of each cycle, supported by observational data collected throughout the learning process. Prior to the intervention, students' scientific reasoning abilities were categorized as relatively low. Most students experienced difficulties in identifying scientific problems, formulating simple hypotheses, analyzing observational data, and drawing logical conclusions based on empirical evidence. The pre-intervention test results revealed an average score of 56.8, with a learning mastery percentage of 36%. These findings indicate that the previous science instruction had not fully facilitated the development of students' scientific thinking skills.

In Cycle I, the discovery learning model was implemented through the stages of stimulation, problem identification, data collection, data processing, verification, and generalization. At this stage, students were introduced to simple investigative activities through direct observation of scientific phenomena. Observation results indicated that some students began to demonstrate active engagement in the learning process, particularly during the data collection stage. However, many students still encountered difficulties when asked to formulate hypotheses and connect observational findings with scientific concepts. They tended to rely on teacher guidance and were not yet accustomed to presenting arguments supported by evidence. The test results at the end of Cycle I showed improvement, with an average score increasing to 66.5 and the learning mastery percentage reaching 52%. Although progress was evident, the reflection results suggested that instructional improvements were still necessary, particularly in providing scaffolding during the data analysis and verification stages. Based on the reflections from Cycle I, several improvements were introduced in Cycle II, including the development of more structured investigative worksheets, the use of guiding questions, and the strengthening of group discussions to better support students in formulating hypotheses and analyzing data.

The implementation of Cycle II demonstrated increased student learning activity. Students became more actively involved in discussions, began expressing predictions, and

showed greater confidence in presenting observational findings in front of the class. Nevertheless, some students still experienced difficulties in constructing systematic scientific conclusions. The test results at the end of Cycle II indicated further improvement, with the average student score increasing to 76.9 and the learning mastery percentage reaching 72%. This improvement suggests that the revised instructional strategies had begun to positively influence students' scientific reasoning abilities. However, the predetermined success criterion namely, that at least 80% of students achieve mastery had not yet been attained; therefore, the study proceeded to the next cycle.

In Cycle III, the intervention focused on strengthening scientific argumentation through reflective discussions, presentations of investigative findings, and direct feedback on students' reasoning processes. The teacher provided more intensive guidance to help students connect observational data with the scientific concepts being studied. The implementation of Cycle III demonstrated significant changes in students' learning activities. Students appeared more confident in asking questions, proposing hypotheses, interpreting data, and drawing conclusions based on empirical evidence. Classroom discussions became more interactive, and students began to exhibit stronger scientific argumentation skills. These findings indicate that the structured implementation of the discovery learning model progressively improved students' scientific reasoning abilities across each cycle. The gradual improvement suggests that the effectiveness of discovery learning depends not only on its procedural stages but also on the provision of appropriate instructional scaffolding that supports students' cognitive development. This finding supports constructivist perspectives emphasizing that meaningful scientific understanding is best developed through active engagement, guided inquiry, and reflective reasoning processes.

The results of this study further confirm that discovery learning can serve as an effective instructional model for promoting scientific reasoning in elementary science education when systematically designed and implemented. The improvement in students' conceptual understanding and reasoning performance demonstrates that active participation in inquiry-based learning enables students to construct scientific knowledge more meaningfully and develop stronger evidence-based thinking skills. The following section presents the results of students' content mastery.

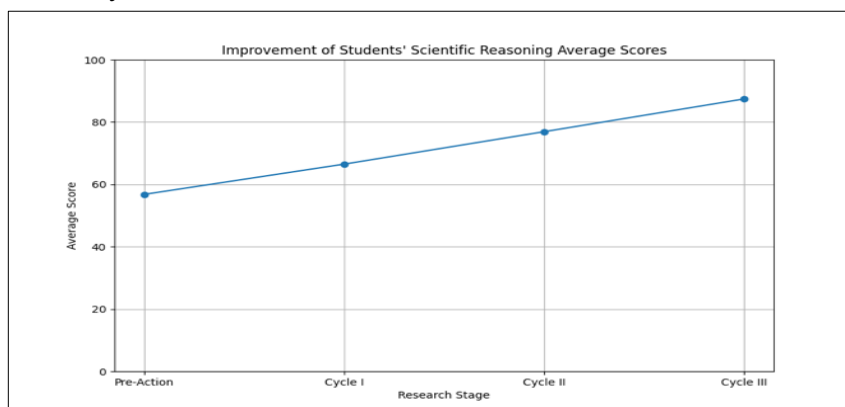


Figure 2. Students Scientific Reasoning Scores

The test results at the end of Cycle III demonstrated optimal improvement. The average student score increased to 87.4, with the learning mastery percentage reaching 92%. This significant improvement indicates that the majority of students were able to achieve the predetermined scientific reasoning indicators. More specifically, the improvement in students' scientific reasoning abilities across the intervention cycles is presented in Table 1.

Table 1. Skor *Scientific Reasoning* Siswa

Research Stage	Average Score	Mastery Percentage
Pre-Action	56.8	36%
Cycle I		52%
Cycle II	76.9	72%
Cycle III	87.4	92%

Table 1 demonstrates a consistent improvement in students' scientific reasoning abilities across each research cycle. During the pre-intervention stage, the average student score remained in the low category, with the learning mastery level falling below the predetermined research success criteria. This condition indicates that prior to the intervention, most students experienced difficulties in understanding scientific reasoning processes, particularly in identifying problems, formulating hypotheses, analyzing data, and drawing logical conclusions.

Following the implementation of the Discovery Learning model in Cycle I, both the average scores and the percentage of learning mastery showed improvement. Although this increase had not yet reached the established target, the results indicate that students had begun to adapt to a learning process that required active engagement in independently constructing concepts. At this stage, students started to demonstrate initial abilities in observation and data collection, although they still required intensive teacher guidance during the analysis and verification stages. A more substantial improvement was observed in Cycle II. This finding suggests that the instructional revisions made based on reflections from the previous cycle had a positive impact on the development of students' scientific reasoning. The use of more structured investigative worksheets, guiding questions, and strengthened group discussions effectively supported students in formulating hypotheses and systematically connecting observational findings with scientific concepts. In Cycle III, the improvement in average scores and learning mastery percentages reached optimal results. Most students were able to demonstrate stronger scientific reasoning abilities, as reflected in their capacity to present scientific arguments, logically interpret data, and draw conclusions based on empirical evidence. This achievement indicates that the gradual and sustained implementation of Discovery Learning created an effective learning experience for fostering students' scientific thinking skills.

Overall, the increase in average scores from the pre-intervention stage to Cycle III, amounting to 30.6 points, along with the 56% increase in learning mastery, confirms that the Discovery Learning model made a significant contribution to the enhancement of students' scientific reasoning abilities. These findings suggest that student-centered instruction supported by structured exploration and reflective processes can serve as an effective strategy for improving the quality of science education in elementary schools. The data was consistent with the findings of Parmin (2022), scientific reasoning has been shown to provide significant benefits in the learning process. The data on the improvement of students' scientific reasoning based on specific indicators are presented in the following table.

Table 2. Scientific Reasoning
Score for Each Indicator

Scientific Indicator	Reasoning	Pre-Action	Cycle I	Cycle II	Cycle III	Improve ment
Identifying problems	scientific	58.2	68.4	78.6	88.9	30.7
Formulating hypotheses		52.4	61.8	73.5	85.6	33.2
Collecting and analyzing data	and	57.1	66.2	76.8	87.2	30.1
Connecting with scientific concepts	evidence	55.6	65.4	76.2	86.8	31.2
Drawing conclusions	logical	60.7	70.8	79.4	88.5	27.8
Average		56.8	66.5	76.9	87.4	30.6

Table 2 indicates that the improvement in students' scientific reasoning occurred comprehensively across all measured indicators throughout the implementation of the study. Each indicator demonstrated consistent development from the pre-intervention stage through Cycle III, suggesting that the implementation of the Discovery Learning model had a positive impact on multiple dimensions of students' scientific thinking abilities.

The most substantial improvement was observed in the formulating hypotheses indicator, which increased by 33.2 points. This finding suggests that students experienced significant development in their ability to construct scientific predictions based on observed phenomena. At the beginning of the study, most students encountered difficulties in formulating hypotheses, as they were not yet accustomed to connecting prior knowledge with the problems presented. However, through discovery-based learning activities emphasizing exploration and guiding questions, students became increasingly skilled in developing logical predictions.

The connecting evidence with scientific concepts indicator also showed a notable improvement of 31.2 points. This result indicates that students became more capable of linking empirical observations to the scientific concepts being studied. This ability represents a critical component of scientific reasoning, as it requires students not only to observe phenomena but also to interpret the scientific significance of the data obtained.

Similarly, the identifying scientific problems indicator improved by 30.7 points, demonstrating that students became more proficient in recognizing scientific issues and formulating investigative questions more accurately. Meanwhile, the collecting and analyzing data indicator increased by 30.1 points, indicating that students gradually developed the ability to conduct observations more systematically and process observational information more effectively. The drawing logical conclusions indicator improved by 27.8 points. Although this was the lowest increase among all indicators, it still represents substantial progress. Drawing logical conclusions requires more complex cognitive processes, as students must synthesize data, relate it to scientific concepts, and construct evidence-based arguments. Therefore, the improvement in this indicator suggests that students gradually developed higher-order thinking skills. Overall, students' average scientific reasoning score increased by 30.6 points from the pre-intervention stage to Cycle III. These findings indicate that the implementation of Discovery Learning not only improved overall learning outcomes but also strengthened each specific component of scientific reasoning.

In addition to the improvement in test results, classroom observations also revealed significant changes in students' learning behaviors. At the beginning of the study, students tended to be passive, relied heavily on teacher instructions, and lacked confidence in expressing their ideas. However, following the gradual implementation of the Discovery Learning model across the three cycles, students demonstrated notable positive changes in learning engagement. They became more active in conducting observations, participating in collaborative discussions, formulating predictions, posing questions, and presenting scientific arguments based on observational findings.

These behavioral changes indicate that discovery-based learning not only influences cognitive development but also fosters scientific attitudes and enhances students' self-confidence throughout the science learning process.

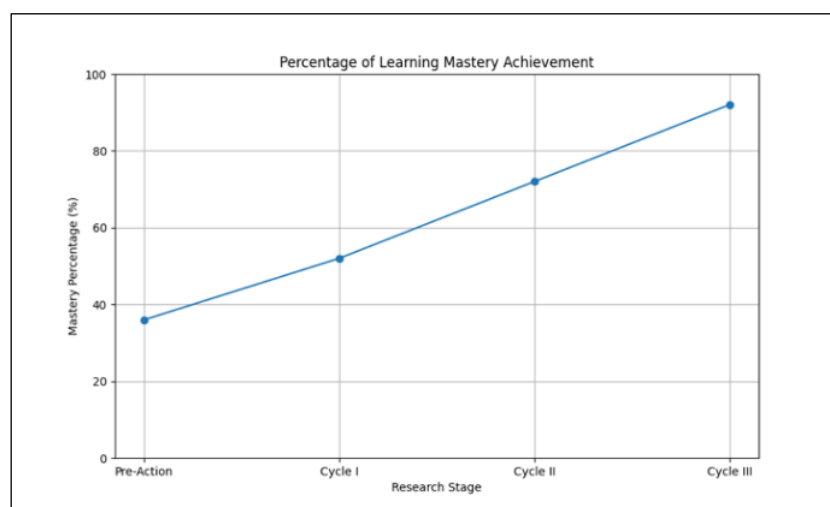


Figure 3. Learning Mastery Achievement

Based on the predetermined success criterion, namely that at least 80% of students achieve learning mastery, the study was declared successful in Cycle III. The findings of this

study demonstrate that the implementation of the Discovery Learning model was effective in enhancing students' scientific reasoning abilities in elementary science instruction.

To provide a clearer illustration of the improvement in students' scientific reasoning abilities across the intervention cycles, the data are presented in Figure 4.

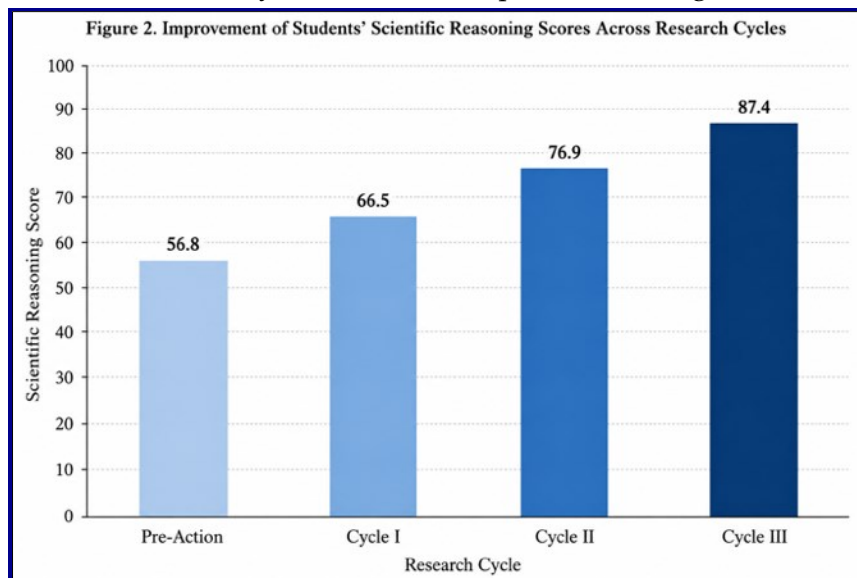


Figure 4. Students Scientific Reasoning Improvement

Figure 4 illustrates a clear upward trend in students' scientific reasoning performance throughout the implementation of the classroom action research cycles. The graph indicates that each cycle of Discovery Learning contributed progressively to strengthening students' reasoning abilities, with no decline observed at any stage. This pattern reflects the effectiveness of continuous instructional refinement and suggests that repeated exposure to inquiry-based learning activities enabled students to gradually develop stronger analytical thinking, scientific interpretation, and evidence-based reasoning skills. The steady progression shown in the graph also confirms that the learning intervention was implemented consistently and produced sustainable improvement in students' scientific reasoning development.

Discussion

This study aimed to improve students' scientific reasoning through the implementation of the Discovery Learning model in elementary science learning. The research findings systematically show that the intervention was successful in enhancing students' scientific reasoning across all action cycles. The quantitative data indicate a consistent increase in the average scientific reasoning score, from 56.8 in the pre-action stage to 66.5 in Cycle I, 76.9 in Cycle II, and 87.4 in Cycle III. Likewise, learning mastery improved significantly from 36% before the intervention to 92% at the end of Cycle III. These findings provide factual evidence that Discovery Learning contributed positively to students' reasoning development.

The progressive improvement across cycles demonstrates that scientific reasoning is not developed instantly but through repeated inquiry experiences. In Cycle I, students showed limited ability to formulate hypotheses and interpret evidence, which reflects their initial

dependence on teacher guidance. This finding indicates that elementary students often lack prior experience in engaging with scientific investigation processes. However, after improvements in instructional scaffolding during Cycle II and Cycle III, students demonstrated stronger analytical thinking, better evidence interpretation, and more logical conclusion-making. This suggests that structured and guided implementation of Discovery Learning is crucial for maximizing learning outcomes.

The impact of these findings is significant for elementary science education. First, the implementation of Discovery Learning shifted classroom interaction from teacher-centered instruction to student-centered inquiry. Students became more actively involved in observing phenomena, asking questions, discussing findings, and constructing explanations based on evidence. This active participation strengthened not only cognitive achievement but also scientific attitudes such as curiosity, critical inquiry, and confidence in expressing ideas.

Second, the findings show that Discovery Learning improved all indicators of scientific reasoning. The highest increase occurred in formulating hypotheses (33.2 points), followed by connecting evidence with scientific concepts (31.2 points). This indicates that the model was particularly effective in training students to think predictively and analytically. These competencies are essential because scientific reasoning forms the foundation for problem-solving and evidence-based decision-making in science learning. Third, the results imply that repeated reflective cycles in classroom action research enhance instructional effectiveness. The reflection process enabled the teacher to identify weaknesses in each cycle and make appropriate pedagogical adjustments, such as providing guiding questions, structured worksheets, and more focused feedback. This confirms that the success of innovative instructional models depends not only on the model itself but also on the quality of its implementation.

The findings of this study are consistent with previous research on Discovery Learning. Research by Jerome Bruner emphasizes that discovery-based instruction allows learners to construct understanding through active exploration, leading to deeper conceptual comprehension. Similarly, studies conducted by other researchers have reported that Discovery Learning significantly improves critical thinking and conceptual mastery in science education. The present findings support these conclusions by showing measurable improvement in scientific reasoning among elementary school students. This study also aligns with research indicating that inquiry-oriented learning environments foster scientific literacy by encouraging students to formulate questions, test assumptions, and evaluate evidence systematically. Previous classroom-based studies reported that Discovery Learning improves science process skills and analytical reasoning. The current study extends these findings by demonstrating that Discovery Learning specifically strengthens scientific reasoning indicators such as hypothesis formulation, data interpretation, and logical conclusion drawing in the context of elementary science instruction.

However, the findings differ from studies that suggest Discovery Learning may be less effective for younger learners due to cognitive overload. Some researchers argue that elementary students may struggle with independent exploration when instructional guidance is insufficient. The results of this study provide an important clarification: Discovery Learning is effective for elementary students when supported by appropriate scaffolding. The improvements observed after revisions in Cycle II and Cycle III confirm that teacher facilitation plays a critical role in ensuring successful implementation. From a broader educational perspective, these findings have practical implications for science teaching in elementary schools. Teachers should design inquiry-based learning environments that provide sufficient structure while maintaining opportunities for student exploration. Educational institutions should also support teacher professional development in designing and implementing Discovery Learning strategies effectively.

Despite the positive findings, this study has limitations. The research involved only one class with a relatively small sample size, which limits generalizability. In addition, the study focused solely on scientific reasoning in science learning. Future research should involve larger samples, different grade levels, and comparative experimental designs to further validate the effectiveness of Discovery Learning across broader educational contexts. Overall, this study confirms that Discovery Learning is an effective instructional approach for improving students' scientific reasoning. Its systematic implementation fosters active inquiry, strengthens analytical thinking, and contributes to improving the overall quality of elementary science learning.

CONCLUSION

This study concludes that the implementation of the Discovery Learning model effectively achieved the research objective of improving students' scientific reasoning in elementary science learning. The main discovery of this research is that systematic inquiry activities through the stages of Discovery Learning can strengthen students' ability to think analytically, construct evidence-based explanations, and develop logical conclusions. The study also reveals that the effectiveness of this model depends on structured teacher guidance and continuous reflective improvement during the learning process.

These findings contribute to the development of elementary science instruction by emphasizing the importance of student-centered learning environments that actively engage learners in scientific investigation. Discovery Learning can therefore be considered a relevant instructional approach for fostering scientific literacy and higher-order thinking skills in elementary education. Future research is recommended to examine the implementation of Discovery Learning in broader educational settings, across different grade levels, and through comparative experimental designs. Ongoing developments in educational technology also provide opportunities for further studies exploring the integration of Discovery Learning with digital and adaptive learning platforms to support scientific reasoning development more effectively.

REFERENCES

- Bhaw, J. Kriek, & M. Lemmer. (2023). Insights from coherence in students' scientific reasoning skills. *Heliyon*, 9(7), e17349. <https://doi.org/10.1016/j.heliyon.2023.e17349>.
- Ying Zhang & Chi-Kuang Wen. (2019). *Statistics as Part of Scientific Reasoning in Plant Sciences: Overlooked Issues and Recommended Solutions*. *Molecular Plant*, 12(1), 7–9. <https://doi.org/10.1016/j.molp.2018.11.001>.
- Manel BenSassi & Henda Ben Ghezala. (2023). *Fuzzy knowledge based assessment system for K-12 Scientific Reasoning Competencies*. *Procedia Computer Science*, 225, 3123–3132. <https://doi.org/10.1016/j.procs.2023.10.306>.
- Gattinoni, L, John J. Marini, Davide Chiumello, Mattia Busana, & Luigi Camporota. (2020). *COVID-19: scientific reasoning, pragmatism and emotional bias*. *Annals of Intensive Care*, 10(1), 134. <https://doi.org/10.1186/s13613-020-00756-7>.
- Osterhaus, C., Lin, X. & Koerber, S. Measuring scientific reasoning in kindergarten and elementary school: validating the Chinese version of the Science-K Inventory. *Educ Res Policy Prac* (2023). <https://doi.org/10.1007/s10671-023-09332-9>
- Krell, M., Khan, S., Vergara, C. 2023. Pre-Service Science Teachers' Scientific Reasoning Competencies: Analysing the Impact of Contributing Factors. *Res Sci Educ* 53, 59–79 (2023). <https://doi.org/10.1007/s11165-022-10045-x>
- Vaesen, K., Houkes, W. A new framework for teaching scientific reasoning to students from application-oriented sciences. *Euro Jnl Phil Sci* 11, 56 (2021). <https://doi.org/10.1007/s13194-021-00379-0>
- Georgiou N, Delfabbro P, Balzan R. Latent profile analysis of schizotypy, autistic traits and conspiracy theory beliefs: Associations with cognitive flexibility and scientific reasoning performance. *Journal of Experimental Psychopathology*. 2022;13(3). doi:10.1177/20438087221125046
- Convertini, J. An Interdisciplinary Approach to Investigate Preschool children's Implicit Inferential Reasoning in Scientific Activities. *Res Sci Educ* 51, 171–186 (2021). <https://doi.org/10.1007/s11165-020-09957-3>
- Ben-Horin, H., Kali, Y., & Tal, T. (2023). The Fifth Dimension in Socio-Scientific Reasoning: Promoting Decision-Making about Socio-Scientific Issues in a Community. *Sustainability*, 15(12), 9708. <https://doi.org/10.3390/su15129708>
- Tabak, I., & Dubovi, I. (2023). What drives the public's use of data? The mediating role of trust in science and data literacy in functional scientific reasoning concerning COVID-19. *Science Education*, 107, 1071–1100. <https://doi.org/10.1002/sce.21789>
- Coleman AB, Lorenzo K, McLamb F, Sanku A, Khan S, Bozinovic G. Imagining, designing, and interpreting experiments: Using quantitative assessment to improve instruction in scientific reasoning. *Biochem Mol Biol Educ*. 2023; 51(3): 286–301. <https://doi.org/10.1002/bmb.21727>
- Fabre, R., Azeroual, O., Schöpfel, J., Bellot, P., & Egret, D. (2023). A Multiverse Graph to Help Scientific Reasoning from Web Usage: Interpretable Patterns of Assessor Shifts in GRAPHYP. *Future Internet*, 15(4), 147. <https://doi.org/10.3390/fi15040147>
- Malone, K. L., & Schuchardt, A. (2023). Modelling-based pedagogy as a theme across science disciplines—Effects on scientific reasoning and content understanding. *European Journal of Science and Mathematics Education*, 11(4), 717-737. <https://doi.org/10.30935/scimath/13516>

- Parmin, P., Khusniati, M., El Islami, R.A., Deta, U.A., & Saregar, A. (2022). Online Scientific Argumentation Strategy on Improving Pre-Service Science Teachers' Scientific Reasoning through Experiment Activity: A Case Study in Indonesia. *Perspectives of Science and Education*.
- Sapia, P., Napoli, F., & Bozzo, G. (2022). The Lawson's Test for Scientific Reasoning as a Predictor for University Formative Success: A Prospective Study. *Education Sciences*, 12(11), 814. <https://doi.org/10.3390/educsci12110814>
- Choowong, K., & Worapun, W. (2021). The Development of Scientific Reasoning Ability on Concept of Light and Image of Grade 9 Students by Using Inquiry-Based Learning 5E with Prediction Observation and Explanation Strategy. *Journal of Education and Learning*.
- Sahin, F., & Sasmaz Oren, F. (2022). Laboratory as an Instrument in Improving the Scientific Reasoning Skills of Pre-Service Science Teachers with Different Cognitive Styles. *Science Insights Education Frontiers*.
- Lazonder, A. W., & Janssen, N. (2021). Development and initial validation of a performance-based scientific reasoning test for children. *Studies in Educational Evaluation*, 68, 100951. <https://doi.org/10.1016/j.stueduc.2020.100951>
- Tofel-Grehl, C., Searle, K.A. & Ball, D. Thinking Thru Making: Mapping Computational Thinking Practices onto Scientific Reasoning. *J Sci Educ Technol* 31, 730–746 (2022). <https://doi.org/10.1007/s10956-022-09989-6>