International Journal of Theory and Application in Elementary and Secondary School Education
(IJTAESE) Vol. 09 No. 01 (2026) https://10.33830/ijtaese.v8i01.14941

Check for updates

Research Paper

developing scientific and causal reasoning through biodiversity learning based on environmental exploration among fifth-grade students

Dewi Rahmawati[1], Insih Wilujeng[1], Woro Sri Hastuti[1], Allisya Oktaviasary[1]
[1]Universitas Negeri Yogyakarta

*Corresponding Author: dewi685.2025@student.uny.ac.id

Received: 30 January 2026	Revised: 03 March 2026	Accepted: 28 April 2026	Online: 30 April 2026

Abstract
Elementary school students frequently struggle to apply causal and scientific reasoning to environmental phenomena, yet elementary science education has not sufficiently integrated evidence-based thinking and contextual learning to address this challenge. However, science instruction at the elementary level remains predominantly focused on memorization-oriented learning, limiting students' opportunities to develop scientific thinking through authentic investigation activities. This study investigated the development of scientific reasoning and causal reasoning among fifth-grade students through biodiversity learning based on environmental exploration at SD Negeri Tibayan 2, Jatinom, Klaten. The study approach using phenomenological case study design. On this rearch using participans 20 students in five-grade elementary. Data were collected through participatory observation, semi-structured interviews, documentation, and analysis of students' worksheets and visual representations during environmental exploration activities. The findings revealed that direct environmental exploration supported students' students' abilities to identify biodiversity phenomena, construct simple causal relationships, and develop evidence-based scientific explanations derived from empirical observations. Furthermore, exploration activities development the students' observational skills, ecological awareness, and contextual understanding of environmental relationships. Nevertheless, students' reasoning patterns remained largely concrete and descriptive, indicating the need for sustained inquiry-based learning to support the development of higher-order scientific reasoning. These findings demonstrate that environmental exploration-based biodiversity learning provides a meaningful pedagogical approach for strengthening scientific reasoning in elementary science education.

Keywords *Biodiversity learning, Causal reasoning, Environmental exploration, Elementary science education, Scientific reasoning*

INTRODUCTION

Twenty-first-century science education emphasizes the development of scientific reasoning as a fundamental competency (Osborne, 2025) that should be introduced at the elementary school level because it supports students' critical thinking, problem-solving abilities, and evidence-based decision-making skills (Bodas & AKelemen, 2026). Scientific reasoning refers not only to students' understanding of scientific concepts but also to their ability to analyze evidence, identify causal relationships, formulate scientific explanations, and draw conclusions based on empirical observations (Shavlik & Köksal, 2022). In elementary science learning, these competencies are essential because they enable students to understand natural phenomena systematically and critically.

The importance of scientific reasoning development, research focusing specifically on the development of scientific reasoning and causal reasoning among elementary school students, particularly in biodiversity learning contexts (Yatin, Sapuadi, &Yuliarti, 2025). Most previous studies have focused primarily on cognitive learning outcomes rather than examining students' scientific thinking processes during learning activities (Osborne & Patterson, 2011). Furthermore, in many elementary school classrooms, science learning remains predominantly characterized by memorization-oriented instruction and teacher-centered approaches that limit students' opportunities to engage in investigative learning experiences (Brian J. Reiser, Leema K. Berland, 2020). Students are frequently required to memorize scientific concepts without opportunities to investigate environmental phenomena directly or connect scientific concepts with real environmental situations in their surroundings (Zhang & Yan, 2022). Consequently, students often develop superficial understanding of biodiversity concepts without being able to explain ecological relationships scientifically or construct scientific explanations based on empirical evidence (Simon et al., 2020).

One important context for developing scientific reasoning in elementary science education is biodiversity learning. Biodiversity topics are closely related to students' daily experiences because students interact directly with plants, animals, and environmental conditions within their surroundings (Simon et al., 2020). This contextual connection provides opportunities for students to engage in authentic observation and inquiry activities that support conceptual understanding through direct experiences. Biodiversity learning also enables students to understand ecological relationships, interactions among living organisms, and the effects of environmental changes on ecosystem sustainability (Andersson & Johansson, 2024). Through direct engagement with environmental phenomena, students can develop scientific understanding based on observable evidence rather than abstract explanations alone (Forbes, & Biggers, 2020). Exploration-based learning activities encourage students to observe environmental conditions directly and connect empirical findings with scientific concepts.

An important component of scientific reasoning is causal reasoning, which refers to the ability to understand relationships between causes and effects within natural phenomena (Schluer, 2024). Causal reasoning is fundamental in science learning because scientific understanding is constructed through explanations regarding why phenomena occur and how environmental factors influence ecological systems (Morris & Sun, 2026). In biodiversity learning contexts, causal reasoning helps students understand how environmental destruction contributes to habitat loss, how pollution affects ecosystems, and how human activities influence ecological balance (Lederman & Zeidler, 2023).Through causal reasoning, students begin to recognize the interconnected relationships between organisms and environmental conditions (Gochyyev, 2023)

Studies on children's cognitive development indicate that elementary school students develop causal understanding more effectively when they participate in direct observation and authentic environmental exploration activities (Rahayuningtyas, 2026). Experiential learning activities allow students to construct scientific understanding through empirical experiences and environmental interactions. Contextual learning environments enable students to connect scientific ideas with observable environmental phenomena, thereby supporting deeper conceptual understanding (Schneider, 2022). Previous studies have shown that environment-based learning increases students' engagement in science learning and supports more concrete understanding of ecological relationships because students interact directly with natural phenomena (Walker & Nouri, 2025). Environmental exploration activities also encourage students to participate actively in scientific investigations, which contributes to the development of inquiry skills, scientific curiosity, and evidence-based reasoning abilities.

Given the research gap identified above specifically the lack of studies examining elementary school students' scientific reasoning and causal reasoning in biodiversity learning contexts, particularly in rural educational settings this study aims to investigate students' scientific reasoning skills through outdoor biodiversity learning activities. Specifically, this study seeks to answer the following research about 3 question, and the consist of : 1) To what extent can elementary school students demonstrate scientific reasoning skills, including using observational findings as evidence, explaining cause-and-effect relationships, drawing conclusions based on observations, and constructing scientific explanations, through outdoor biodiversity learning activities?; 2) What is the level of students' understanding (Good, Fair, Developing, or Poor) for each scientific reasoning indicator based on their performance in outdoor biodiversity learning?; and 3)How do students explain cause-and-effect relationships when observing environmental phenomena such as wilted plants, numerous insects in grassy areas, and dry soil in open, unshaded areas?

Based on these issues, the research question of this study is: *How do fifth-grade students at SD Negeri Tibayan 2 construct scientific reasoning and causal reasoning through biodiversity learning based on environmental exploration?*. The aim of this study is to analyze how students develop scientific reasoning and causal understanding through direct observation and interaction with biodiversity phenomena in their natural school environment. This study is expected to contribute to the development of scientific reasoning research in elementary education and provide practical guidance for designing contextual, inquiry-based biodiversity learning that enhances students’ scientific thinking skills.

LITERATUR REVIEW

1. Scientific Reasoning

Scientific reasoning refers to the cognitive ability used to construct scientific understanding through the analysis of evidence, evaluation of data, and formulation of logical conclusions based on empirical observations (Nouri & Saberi, 2024: Gijse, 2025). In science education, scientific reasoning is essential because it enables students to develop analytical and reflective thinking skills through inquiry and investigation processes rather than relying solely on conceptual memorization (Miriam J. Rhode, Martine A. R. Gijse, 2025). Scientific reasoning develops through active interaction between learners’ experiences and their cognitive structures (Rui Guo, Nirat Jantharaji & Thongpanit, 2025), allowing students to build knowledge through direct engagement with scientific phenomena (Jimenez,2024) Scientific reasoning includes several interconnected competencies, such as evidence-based thinking, data interpretation, inferential reasoning, and scientific conclusion-making (Ha, H., Park, W., & Song, 2023). At the elementary school level, these abilities are generally strengthened through concrete learning experiences involving direct observation and environmental exploration because children at this stage learn more effectively through authentic and observable phenomena (Piaget, 1972). In addition, the development of scientific reasoning contributes significantly to students’ scientific literacy and their ability to critically interpret scientific issues in broader social and environmental contexts (OECD, 2025).

2. Causal Reasoning

Goddu & Gopnik (2024), said Causal reasoning refers to the ability to understand relationships between causes and consequences within particular events or phenomena

(Goddu & Gopnik, 2024),science learning, causal reasoning is important because scientific knowledge is fundamentally constructed through explanations of how and why phenomena occur within natural systems (Depin et al., 2024). The development of causal reasoning among elementary school students is strongly influenced by direct experiences and contextual interactions with real environmental conditions (Sloman, S. A., Barbey, A., & Patterson, 2021). Research indicates that children develop stronger causal understanding when they are involved in experiential learning activities that allow them to directly observe environmental phenomena rather than receiving abstract verbal explanations. Within science education, causal reasoning supports students in understanding ecological relationships, environmental changes, and the impacts of human activities on ecosystems. Furthermore, students with strong causal reasoning abilities tend to construct more coherent scientific explanations because they can connect empirical evidence with logical causal relationships.

3. Biodiversity Learning and the Development of Scientific Reasoning

Biodiversity learning provides a contextual learning environment that enables students to develop scientific understanding through direct interaction with natural surroundings (Kathryn E. Schertz, 2023). In elementary science education, biodiversity instruction not only introduces students to living organisms but also helps them understand ecological relationships and environmental interdependence within ecosystems. Through environmental exploration activities, students are encouraged to observe, classify, and interpret environmental phenomena scientifically. Environment-based biodiversity learning also strengthens students' observational and analytical thinking skills because students actively engage in collecting empirical information from authentic environmental contexts. Activities such as observing plants, identifying insects, and examining environmental conditions support the development of scientific reasoning by allowing students to connect observations with scientific explanations (Erna Roostin, et al, 2026;Shopiah, 2025)). Therefore, biodiversity learning based on environmental exploration can function as an effective pedagogical approach for developing both scientific reasoning and causal reasoning among elementary school students. Environmental exploration-based learning emphasizes direct interaction between students and natural environments. This approach improves students' observational skills, scientific engagement, and conceptual understanding (Jaber, L., & Hammer, 2023).

RESEARCH METHOD

This study employed a qualitative approach using a phenomenological case study design to explore the construction of *scientific reasoning* and causal reasoning among fifth grade (V) students in biodiversity learning based on environmental exploration at SD Negeri Tibayan 2, Jatinom District, Klaten Regency. The qualitative approach was selected because the study focused on obtaining an in-depth understanding of students' scientific thinking processes through contextual learning experiences during environmental exploration activities (Creswell, 2009). The case study design was employed to investigate the learning phenomenon comprehensively within the natural context of a rural elementary school environment that possesses biodiversity potential as a contextual science learning resource. while the phenomenological approach was used to understand students' subjective experiences in constructing scientific reasoning and causal relationships through direct interaction with the school environment. The research participants consisted of fifth-grade (V) students selected through a *purposive sampling* with 20 partipans (12 boys and 8 girls). The study was conducted over 4 (four) weeks, each lasting seasons a 60 minutes once per week. Data were collected through participant observation, semi-structured interviews, documentation, and analysis of students' worksheets. Data analysis employed the interactive model of Miles, Huberman, and Saldaña (2014), which included data reduction, data display, and conclusion drawing. The results are then presented in narrative form articulated within tables, where each table summarizes emerging themes, categories, and representative quotes from participants (Miles & Huberman, 2014). The following rubric was developed to assess and categorize students' ability to identify biodiversity phenomena. The rubric consists of four indicators and four levels of understanding (Good, Fair, Developing, Poor). The complete rubric is presented in Table 1, below.

Table 1. Rubric for Assessing Students' Ability to Identify Biodiversity Phenomena

Indicator	Good (5 poin)	Fair (4 poin)	Developing (3 poin)	Poor (<1%)
Identifying plant species in the school environmen	Identifies ≥5 plant species	Identifies 3-4 plant species	Identifies 1-2 plant species	Cannot identify any plant species
identifying living organisms in the school field area	Finds ≥4 types of organisms	Finds 2-3 types of organisms	Finds 1 type of organism	Finds no organisms
Relating organisms to their habitats	Complete explanation (organism + habitat + reason)	Simple explanation (organism + habitat only)	Incorrect or illogical relationship	Cannot explain any relationship
Explaining environmental conditions affecting organisms' lives	Logical and complete explanation (condition + effect + mechanism)	Effect only (without mechanism)	Vague, limited, or incorrect explanation	Cannot explain any effect

To calculate the percentage of students who demonstrated competence for each indicator, the rubric described above was applied, and the following formula was used:

$$\% = \frac{\text{Number of students classified as Good + Number of students classified as Fair)}}{\text{Total number of students (N)}} \text{ x } 100\%$$

Table 2. Rubric Students' Causal Reasoning Patterns

Observed Phenomenon	Good (3 poin)	Fair (2 poin)	Developing (1 poin)	Poor (0 poin)
Wilted plants : observed in the school garden after three consecutive days without watering during the dry season	Explains lack of water → wilting + mechanism (e.g., water maintains cell turgor, supports photosynthesis)	Explains lack of water → wilting, but no mechanism mentioned	Mentions only one element (cause or effect) or gives reversed relationship	No response or irrelevant answer

Observed Phenomenon	Good (3 poin)	Fair (2 poin)	Developing (1 poin)	Poor (0 poin)
Numerous insects (ants, grasshoppers, and small beetles) found in grassy areas near the schoolyard during morning observations	Explains grass provides habitat + food source + function (e.g., shelter from predators, food, nesting site)	Explains grass as habitat or food source only, without function	Provides inaccurate or illogical relationship (e.g., insects like grass because it is green)	No response or irrelevant answer
Dry soil observed in open, unshaded areas of the schoolyard with minimal plant coverage	Explains hot/dry soil → fewer plants + mechanism (e.g., seeds cannot germinate, roots cannot absorb water)	Explains hot/dry soil → fewer plants, but no mechanism mentioned	Provides partial or inaccurate relationship (e.g., plants do not like hot soil, without explaining effect on growth)	No response or irrelevant answer

Table 3. Rubric Students' Scientific Reasoning Skills

Scientific Reasoning Indicators	Good (3 point)	Fair (2 poin)	Developing (1 poin)	Poor (0 poin)
Using observational findings as evidence	Consistently uses direct observations as relevant and specific evidence	Uses observations as evidence but general or vague	Attempts to use observations but evidence is irrelevant	No evidence used or opinion only
Explaining cause-and-effect relationships	Explains cause and effect completely and logically with accurate reasoning	Explains cause and effect simply without full logic	Mentions only cause or only effect, or relationship is inaccurate	No explanation or irrelevant answer
Drawing conclusions based on observations	Draws logical, accurate conclusions fully supported by observations	Draws conclusions but general, vague, or not fully supported	Attempts to conclude but illogical or not based on observations	No conclusion or completely unrelated

Constructing scientific explanations	Constructs complete scientific explanations using appropriate terminology and conceptual understanding	Constructs simple explanations but lacks scientific terminology or depth	Explanations limited to concrete descriptions (what they saw) without scientific concepts	No explanation or irrelevant to scientific concepts

Finding and Discussion

Finding

This study aimed to explore how fifth-grade (V) students at SD Negeri Tibayan 2 constructed scientific reasoning and causal reasoning through biodiversity learning based on environmental exploration activities. The findings of the study are presented as follows:

1. **Students' Ability to Identify Biodiversity Phenomena**

   The observation results demonstrated that fifth-grade students at SD Negeri Tibayan 2 were able to identify various forms of biodiversity found within the school environment during the exploration activities. The students conducted observations of plants, insects, and environmental conditions that influenced the existence of living organisms. The results presented are in table 1.

Table 4. Students' Ability to Identify Biodiversity Phenomena

No	Observation	Finding research	Percentage students (%)
1	Identifying plant species in the school environment	Students were able to distinguish several types of wild plants and plants around the school	86
2	identifying living organisms in the school field area	Students were able to find insects and small organisms in the school environment	80
3	Relating organisms to their habitats	Students began to understand the relationship between organisms and specific environmental conditions	73
4	Explaining environmental conditions affecting organisms' lives	Students explained the influence of moist soil and sunlight on living organisms	67

Note: Percentages were calculated based on the analysis of three data sources: (1) student worksheets (Items 1-3), (2) observation checklists completed by researchers during outdoor activities, and (3) semi-structured interview responses. A student was counted as demonstrating an indicator if their worksheet response, observed behavior, or interview answer met the rubric criteria for "Good" or "Fair."

Table 4 shows that direct observation experiences helped students understand biodiversity phenomena concretely, although some students still required guidance in understanding ecological relationships more deeply.

2. **Students' Causal Reasoning Patterns**

The results and analysis of students' worksheets demonstrated that students began to construct causal relationships based on the environmental phenomena they observed during the learning activities can be see at table 2.

Table 5. Students' Causal Reasoning Patterns

No	Observed Phenomenon	Students' Cause-and-Effect Explanations	Understanding Category
1	Wilted plants : observed in the school garden after three consecutive days without watering during the dry season	Plants became wilted due to a lack of water	Good
2	Numerous insects (ants, grasshoppers, and small beetles) found in grassy areas near the schoolyard during morning observations	Grass serves as a habitat and food source for insects	Good
3	Dry soil observed in open, unshaded areas of the schoolyard with minimal plant coverage	Fewer plants grow because the soil is hot and dry	Fair

Table 5 shows that the students began to construct simple causal reasoning patterns based on the results of environmental observations. These findings suggest that environmental exploration-based learning provided an initial stimulus for the development of elementary students' causal reasoning skills.

3. **Students' Scientific Reasoning Skills**

The analysis of students' worksheets revealed the development of scientific reasoning skills in constructing scientific explanations based on observational findings.

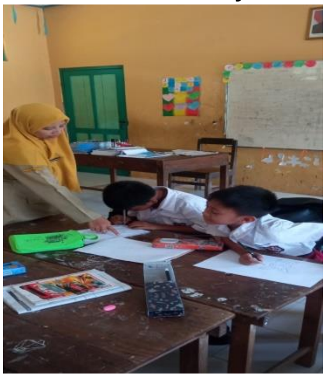
Table 6. Students' Scientific Reasoning Skills

No	Scientific Reasoning Indicators	Research Findings	Understanding Category
1	Using observational findings as evidence	Students used direct observations in their responses	Good
2	Explaining cause-and-effect relationships	Students were able to explain simple relationships between phenomena	Good
3	Drawing conclusions based on observations	Students began to formulate simple conclusions	Fair
4	Constructing scientific explanations	Students' explanations were still limited to concrete observations	Developing

Table 6 shows that the students began to use observational findings as the basis for constructing scientific explanations. Most students were able to relate their observations to simple explanations regarding environmental phenomena. However, students' ability to construct more complex scientific explanations still required reinforcement through deeper and more continuous investigative activities

4. **Visual Representation of Biodiversity Observations**

The findings also revealed that students not only conducted observations of biodiversity objects within the school environment but also represented their observations through drawing activities involving plants and animals found during field exploration. The activity of drawing observational findings demonstrated that visual representation assisted students in constructing scientific understanding through the interpretation of observed objects. According to (Bruner, 1961), visual representation supports students in developing conceptual understanding through the iconic representation stage before progressing toward abstract understanding. These findings are also consistent with the study conducted by Ainsworth et al. (2023), which revealed that visual representation in science learning enhances elementary students' observational skills and scientific explanation abilities. The result is presented in the visual drawing shown in the picture below



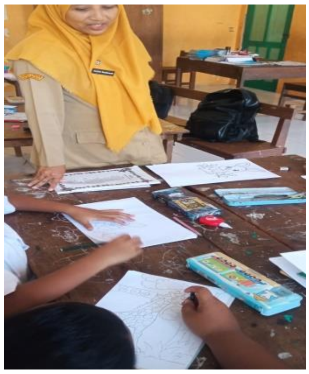


Figure 1. Students' Construction of Scientific Reasoning through Visual Representation in Environmental Exploration-Based Biodiversity Learning

Figure 1 illustrates fifth-grade (V) students at SD Negeri Tibayan 2 engaging in visual representation activities following direct environmental exploration. Through drawing activities, students documented and interpreted biodiversity objects observed within the school environment, including plants, insects, and environmental conditions surrounding their habitats. The visual representations produced by students reflected not only observational outcomes but also the development of scientific reasoning through the identification of organism characteristics, habitat relationships, and simple ecological interactions. Furthermore, these activities demonstrated students' emerging ability to transform empirical observations into concrete scientific representations, indicating the development of evidence-based interpretation and causal understanding derived from authentic environmental experiences. The integration of drawing activities within environmental exploration learning also strengthened students' reflective thinking processes by enabling them to reconstruct observational findings into meaningful scientific explanations.

DISCUSSION

The findings of this study demonstrate that biodiversity learning based on environmental exploration contributed significantly to the development of scientific reasoning and causal reasoning among fifth-grade students at SD Negeri Tibayan 2. Through direct observation activities conducted in the school environment, students were able to construct scientific understanding through contextual and empirical experiences. Learning activities carried out in authentic environments enabled students to connect biodiversity concepts with real environmental phenomena observed directly in the field. This finding indicates suggests that exploration-based learning provides more meaningful learning experiences than conventional classroom instruction that primarily emphasizes memorization and verbal explanation of concepts. Students developed scientific understanding not only by receiving information from teachers but also by interacting directly with plants, insects, and environmental conditions surrounding the school environment.

The study also revealed that direct environmental observation enhanced students' observational and analytical skills. Students became more capable of identifying biodiversity objects and understanding relationships, between organisms and environmental conditions. These findings support who stated that natural environment-based learning improves students' observational abilities and cognitive engagement because students experience authentic interactions with environmental phenomena (Kyra Ricci, Kathleen Lu, Grascen Shidemantle, 2024;Javier Cantillo, 2025). Outdoor learning activities support deeper conceptual understanding because students can directly relate scientific concepts to real-world environmental conditions. Research has shown the outdoor learning can enchanted elementary students ecological relationships, such as understanding that plants insects inhabit grassy areas because they provide shelter and food resource (Ayotte & Beaudet, 2023).

Improving observational skills, environmental exploration activities contributed to the development of students' causal reasoning abilities. Students gradually developed the ability to explain cause-and-effect relationships related to environmental phenomena observed during exploration activities. This finding aligns with Kuhn (2021), who argued that causal reasoning develops more effectively when students are involved in investigating authentic scientific phenomena that enable them to connect causes with consequences (Kuhn, 2021). Through biodiversity exploration activities, students began to recognize relationships between environmental conditions and the survival of living organisms, although most explanations remained relatively simple and concrete. The findings further showed that exploration-based learning supported the development of evidence-based scientific reasoning. Students started to construct explanations based on observational evidence collected during environmental exploration activities. Osborne and Patterson (2024) explained that scientific reasoning develops when students engage in data collection, observation interpretation, and evidence-based explanation construction. In this study, students demonstrated emerging abilities to explain environmental phenomena using evidence obtained through direct observation. These experiences strengthened the connection between scientific concepts and students' everyday experiences, making science learning more contextual and meaningful (Osborne, J., & Patterson, 2011).

The emphasized that scientific discussion activities strengthen evidence-based argumentation and support the development of scientific reasoning processes Erduran, 2023). Furthermore, visual representation activities through drawing biodiversity objects helped students organize and interpret observational findings more concretely. According to Prain (2023), visual representation supports scientific interpretation and conceptual understanding in science learning. This condition corresponds with Piaget's theory of cognitive development, which explains that elementary school students remain in the concrete operational stage where abstract reasoning develops gradually through direct experiences and concrete activities (Tytler, 2023). Therefore, continuous instructional support and inquiry-based learning experiences remain necessary to strengthen students' scientific reasoning abilities. Overall, this study confirms that environmental exploration based biodiversity learning provides important opportunities for elementary school students to develop scientific observation skills, causal reasoning, and evidence-based scientific reasoning through authentic and contextual learning experiences (Muhammad Ikram Abdullah, Javier Kusuma, 2025;Koca, Ceren; Sert, 2026)).

CONCLUSION

This study demonstrates biodiversity learning based on environmental exploration effectively fosters elementary students' scientific reasoning and causal reasoning through direct engagement with authentic environmental phenomena. Students developed the ability to identify biodiversity objects, construct basic cause-and-effect relationships, and formulate evidence-based scientific explanations derived from empirical observations. Nevertheless, students' reasoning patterns remained largely concrete and descriptive, indicating the need for sustained inquiry-oriented instruction to strengthen higher-order analytical thinking. These findings suggest that contextual environmental exploration provides a meaningful pedagogical foundation for developing scientific literacy and ecological understanding in elementary science education.

REFERENCES

Ayotte-Beaudet, et al. (2023). Exploring the impacts of contextualised outdoor science education on learning: the case of primary school students learning about ecosystem relationships. *Journal of Biological Education*, *57*(2), 277–294. https://doi.org/https://doi.org/10.1080/00219266.2021.1909634

Bodas, A. &, & AKelemen, D. (2026). Conceptualizing science as explanatory predicts elementary students' life science learning: The relative influence of science conceptions, science identity and mindset. *Journal of Applied Developmental Psychology*, *104*, 101948.

Brian J. Reiser, Leema K. Berland, and L. K. (2020). Engaging Students in the Scientific Practices of Explanation and Argumentation : Understanding A Framework for K–12 Science Education. In *Journal of Research in Science Teaching.* National Academies Press. https://doi.org/10.1002/tea.21625Digital Object Identifier (DOI)

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, *31*.

Creswell, J. W. (2009). Reseacrh Design Qualitative, Quantitative and Mixed Methods Approaches. In *Third Edition* (Third). Sage.

Depin, Nurwahid, H., Sulla, F. Y., & Barella, Y. (2024). Inquiry Learning: Pengertian, Sintaks Dan Contoh Implementasi Di Kelas. *Internasional Journal and Education Learning*, *1*(2), 1–5.

Erna Roostin, Ajeng Sri HikmayaniErna Roostin, A. S. H. (2026). Natural Environment Based Science Learning to Improve Critical Thinking and Creativity Skills in Early Childhood. *Jurnal Pendidikan Dan Pengasuhan Anak*, *7*(1), 46–60.

Ha, H., Park, W., & Song, J. (2023). Preservice elementary teachers' socioscientific reasoning during a decision-making activity in the context of COVID-19. *Science & Education*, *32*(6).

Jaber, L., & Hammer, D. (2023). Engaging students in authentic science learning: Emotion, meaning-making, and disciplinary engagement. *Science Education*, *107*(3), 1–25.

Javier Cantillo, B. N. O. M. (2025). Recognising the need for biodiversity knowledge for engineering students – a case study in Norway. *International Journal of Sustainability in Higher Education*, *26*(4), 755–772. https://doi.org/https://doi.org/10.1108/IJSHE-01-2024-0026

Jimenez, P. C., Alred, A. R., & Dauer, J. M. (2024). Describing undergraduate students' reasoning and use of evidence during argumentation about socioscientific issues systems. *Frontiers in Education*, *8*(1).

Joseph Krajcik, Barbara Schneider, et al. (2022). Assessing the Effect of Project-Based Learning on Science Learning in Elementary Schools. *American Educational Research Journal*, *60*(1). https://doi.org/10.3102/00028312221129247

Kathryn E. Schertz, et al. (2023). Nature's path to thinking about others and the surrounding environment. *Journal of Environmental Psychology*, *89*, 102046.

Koca, Ceren; Sert, H. (2026). Engaging with the Nature of Science in Early Childhood: A Biodiversity-Based Educational Intervention. *International Journal of Early Childhood*, 1–6.

Kuhn, D. (2021). *Handbook of Childhood Cognitive Development*. Wiley-Blackwell.

Kyra Ricci, Kathleen Lu, Grascen Shidemantle, J. H. (2024). Engaging youth in biodiversity education through visual narrative. *Conservation Biology Published by Wiley Periodicals LLC on Behalf of Society for Conservation Biology.*, 1–12. https://doi.org/10.1111/cobi.14386

Lederman, N. G., & Dana L. Zeidler, and J. S. L. (2023). *HANDBOOK OF RESEARCH ON SCIENCE EDUCATION*. Routledge.

Lundström, M., Andersson, K., & Johansson, E. (2024). Environmental reasoning in biodiversity education. *Ambio*, *53*(5), 1102–1115.

Ma, S., Anderson, R. C., Lin, T.-J., Morris, J. A., & Sun, J. (2026). Aspects of the social construction of causal reasoning. *Journal of the Learning Sciences*, *35*(1), 42–91. https://doi.org/10.1080/10508406.2025.2544619

Maja Schluer, et al. (2024). Navigating causal reasoning in sustainability science. *Ambio, Springer*, *53*, 1618–1631. https://doi.org/10.1007/s13280-024-02047-y

Mariel K. Goddu & Alison GopniK. (2024). The development of human causal learning and reasoning. *Nature Reviews Psychology*, *3*, 319–339. https://doi.org/https://doi.org/10.1038/s44159-024-00300-5

Matthew B. Miles, A. Michael Huberman, & J. S. (2014). *Qualitative data analysis: A methods sourcebook (3rd ed.).* Sage.

Miriam J. Rhode, Martine A. R. Gijse, H. van K. J. V. (2025). The potential functions of reading and writing activities within scientific inquiry in primary education. *Disciplinary and Interdisciplinary Science Education Research*, *7*(9), 2–17.

Muhammad Ikram Abdullah, Javier Kusuma, R. N. A. (2025). Enhancing Middle School

Students' Scientific Literacy Through Inquiry-Based Learning In Environmental Education. *Journal of Science and Mathematics Education*, *1*(4), 1–7. https://doi.org/DOI: https://doi.org/10.70716/josme.v1i4.338

Noushin Nouri & Maryam Saberi. (2024). Promoting Understanding of Three Dimensions of Science Learning Plus Nature of Science Using Phenomenon-Based Learning. *Innovations in Science Teacher Education*, *9*(1), 1–23.

OECD. (2025). *Kerangka Sains 2025* (p. 10). OECD Publishing.

Osborne, J., & Patterson, A. (2011). Scientific argument and explanation: A necessary distinction? *Science Education*, *95*(4), 627–638. https://doi.org/https://doi.org/10.1002/sce.20438

Osborne, J. (2025). Scientific literacy and reasoning in contemporary science education. *International Journal of Science Education*, *15–16*, 2134–2155. https://doi.org/https://doi.org/10.1080/09500693.2024.2331980

Piaget. (1972). Intellectual evolution from adolescence to adulthood. *Human Development*, *15*(1), 20.

Rahayuningtyas, Annisa Cahya, B. U. A. N. K. (2026). The Effect Of The Environmental Exploration Approach On Curiosity, Critical Thinking Skills, And Science Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 98–104.

Rui Guo, Nirat Jantharaji, P., & Thongpanit. (2025). Construct an instructional approach based on collaborative learning and reflective learning for enhance students' analytical thinking and critical thinking skills. *Asian Journal of Contemporary Education*, *8*(2), 115-125. https://doi.org/10.55493/5052.v8i2.5184

Sara J. Dozier , Anna MacPherson 2, Linda Morell , Perman Gochyyev, andMark W. (2023). A Learning Progression for Understanding Interdependent Relationships in Ecosystems. *Sustainability*, *15*(19). https://doi.org/10.3390/su151914212

Shavlik, M., & Köksal, et al. (2022). Contributions of causal reasoning to early scientific literacy. *Journal of Experimental Child Psychology*, *224*. https://doi.org/https://doi.org/10.1016/j.jecp.2022.105509

Shopiah Dhuha Siregar, S. S. & R. R. (2025). Improving student's science process skills through environment-based guided inquiry on biodiversity in outdoor learning. *Jurnal Pendidikan Biologi Indonesia*, *8*(3), 841–847.

Sibel Erduran. (2023). Recent advances in scientific argumentation in science education. *Science Education*, *107*(5), 845–862.

Simon, S., Erduran, S., & Osborne, J. (2020). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education*, *28*(2–3), 235–260. https://doi.org/10.1080/09500690500336957

Sloman, S. A., Barbey, A., & Patterson, R. (2021). Cognitive neuroscience meets the community of knowledge. *Department of Philosophy, Emory University*, 2–27.

Tytler, R. (2023). Re-imagining primary science education through inquiry and context-based learning. *International Journal of Science Education, 45*(6), 987–1005.

https://doi.org/https://doi.org/10.1080/09500693.2023.xxxxxx

Walker, K. I., & Nouri, N. & N. N. (2025). Phenomenon-based learning and storylines in K-12 science education: a systematic review of current research, implementation, and future directions. *Frountier in Education*, *10*, 1–20. https://doi.org/10.3389/feduc.2025.1648234

Yatin Mulyono, Sapuadi Sapuadi, Yuliarti Yuliarti, S. S. (2025). A framework for building scientific literacy through an inquiry learning model using an ethnoscience approach. *International Journal of Advanced and Applied Science*, *11*(8), 158–168.

Zangori, L., Forbes, C. T., & Biggers, M. (2020). Exploring primary students' causal reasoning about ecosystems. *International Journal of Science Education*, *42*(12), 2013–2035.

Zhang, J., & Yan, S. (2022). The relationship between teacher's gender and deep learning strategy: The mediating role of deep learning motivation. *Psychology in the Schools*, *59*(11), 2251–2266.