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Documenting Nature, Constructing Meaning: A Qualitative Case Study of Inquiry-Based Science Learning Integrated with Video-Based Environmental Observation to Foster Critical Thinking in Elementary Education

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Abstract: This study aims to explore how inquiry-based elementary science learning integrated with video-based environmental observation supports the development of students' critical thinking. A qualitative case study design was employed involving fifth-grade students at a public elementary school located in the Lake Tondano area of North Sulawesi, Indonesia. The learning intervention was structured as a project in which students documented lake ecosystem observations through short videos and presented their findings during classroom discussions. Data were collected from student-produced videos, classroom observations, group interviews with students, teacher interviews, and researchers' field notes. The data were analyzed using an inductive thematic approach to identify patterns of critical thinking and students' processes of scientific meaning-making. The findings reveal that inquiry-based video projects enabled students to develop a more concrete and contextual understanding of ecosystems through direct observation, interpretation of local environmental conditions, and construction of causal explanations grounded in visual evidence. Moreover, video documentation and collaborative discussion fostered inquiry-oriented questioning, metacognitive reflection, and awareness of environmental responsibility. These results indicate that integrating inquiry-based learning, local environmental contexts, and simple video production serves as an effective pedagogical approach for fostering elementary students' critical thinking and contextual scientific literacy.

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Introduction

Science education at the elementary level shapes students' ways of thinking, particularly in developing their abilities to observe, question, analyze, and construct meaning from natural phenomena. In recent years, science learning has shifted from traditional, teacher-centered approaches toward more student-centered and inquiry-oriented learning that emphasizes active engagement with everyday contexts (Ndaimehafo A.,et.al., 2024; Önder et al., 2018). This shift is especially relevant in elementary education, where students' cognitive, affective, and psychomotor foundations are still being formed. Within this context, elementary science education offers a strategic space for connecting scientific concepts with the environmental, social, and cultural realities that students encounter in their daily lives.

Environmental-based education has been widely recognized as an essential component of science learning for fostering students' understanding of ecological systems and promoting responsible attitudes toward nature (Collado et al., 2020; Kumar & Choudhary, 2025). Research on outdoor and place-based environmental education indicates that sustained engagement with authentic environments supports students' analytical

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reasoning, reflective thinking, and sensemaking of socio-environmental issues (Collins et al., 2025; Falzon & Conrad, 2024). Through direct observation and guided inquiry, students learn to interpret environmental phenomena, evaluate human–environment interactions, and construct meaning grounded in lived experiences.

Despite these advances, ecosystem learning in elementary classrooms often remains dominated by textbook explanations. Concepts such as food chains, energy flow, and ecological balance are frequently presented abstractly, limiting students' ability to connect scientific ideas with local environmental conditions. Inquiry-based learning addresses this limitation by positioning students as active investigators who observe, question, collect data, and construct explanations (Sam, 2024; Morris, 2025). However, inquiry practices may remain superficial when observations are brief and not systematically documented, restricting opportunities for reflection and deeper reasoning.

To strengthen inquiry processes, this study integrates video documentation as a cognitive tool rather than merely a technological aid. Through recording observations of the Lake Tondano environment, students select phenomena, capture empirical evidence, and interpret ecosystem interactions. Video production enables learners to revisit data, negotiate meaning collaboratively, and present evidence-based explanations. These processes align with core components of critical thinking—analysis, evaluation, inference, and explanation—positioning video-based inquiry as a bridge between direct observation and deeper scientific reasoning (Cattaneo et al., 2024; Navarrete et al., 2025).

Although inquiry-based learning, environmental education, and technology integration have been widely studied, relatively few studies have examined their convergence in elementary science education. Most technology-based research in this field emphasizes teacher-designed digital content such as simulations, augmented reality, or instructional videos (Chang & Hwang, 2018; Seage & Türegün, 2020). Limited attention has been given to how elementary students actively generate digital content to document their own environmental observations and construct scientific meaning. This gap is particularly evident in developing country contexts, where technology integration often remains consumption-oriented rather than creation-oriented.

The need for such an approach is especially urgent in Lake Tondano, a major freshwater ecosystem in North Sulawesi facing ecological pressures including water hyacinth proliferation (*Eichhornia crassipes*), declining water quality, sedimentation, and fluctuating water levels affecting biodiversity and livelihoods. Although these issues are visible in the community, students frequently encounter ecosystem concepts only through simplified textbook representations, making it difficult to connect abstract ideas—such as ecological balance and pollution impact—with local environmental realities.

There remains a lack of qualitative research examining how video-based environmental observation projects support elementary students' critical thinking and scientific meaning construction in authentic ecological contexts. Specifically, little is known about how students document environmental phenomena, interpret ecosystem dynamics, and communicate evidence-based explanations through multimedia grounded in local realities. The novelty of this study lies in integrating inquiry-based learning, environmental education, and student-generated content (SGC) within elementary science education. Rather than positioning technology as a delivery tool, this research conceptualizes video production as a medium for expression, reflection, and epistemic agency. By situating student-generated video within authentic environmental inquiry, this study contributes empirical qualitative evidence on how SGC can function as a pedagogical mechanism for fostering critical thinking and contextual scientific literacy in developing educational contexts.

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This study therefore investigates how inquiry-based learning integrated with video documentation of environmental observations supports the development of elementary students' critical thinking. Conceptually, it extends understandings of inquiry-based learning by positioning video documentation as a cognitive and reflective tool. Empirically, it provides contextual evidence of how locally grounded environmental inquiry can be leveraged to strengthen critical thinking and scientific meaning-making in elementary science education.

Research Method

This study employed a qualitative approach with a case study design to examine how inquiry-based learning integrated with video documentation supports the development of elementary students' critical thinking. A case study was selected because it enables in-depth investigation of a bounded system within its real-life context, particularly when the boundaries between phenomenon and context are not clearly evident (Yin, 2018). Qualitative case study research also allows holistic and interpretive exploration of participants' experiences, instructional processes, and meaning-making (Merriam & Tisdell, 2016; Stake, 1995).

The study was situated in a public elementary school located in the Lake Tondano area, North Sulawesi, Indonesia. Participants consisted of 28 fifth-grade students (aged 10–11 years). Purposive sampling was used based on (1) the inclusion of ecosystem topics in the curriculum and (2) the teacher's willingness to implement inquiry-oriented project-based learning. The classroom teacher collaborated with the researcher as a non-participant observer. Pseudonyms were used to ensure confidentiality.

Lake Tondano was selected as an authentic ecological context closely connected to students' daily lives. The lake includes diverse biotic and abiotic components and visible human impacts, making it a meaningful setting for ecosystem learning. The study was treated as a single, holistic instance of technology-supported inquiry within an authentic environment. The study was conducted over six weeks during regular science instruction. The intervention consisted of a video-based environmental observation project structured in four phases: (1) introduction to ecosystem concepts and formulation of inquiry questions; (2) small-group environmental observations at Lake Tondano with video documentation and field notes; (3) video review, selection, and collaborative interpretation; and (4) classroom presentations followed by peer discussion and feedback. Throughout the process, the teacher provided minimal scaffolding through open-ended questioning to encourage deeper reasoning and reflection.

Multiple data sources were collected to ensure data richness and triangulation. The primary data sources included student-produced videos, classroom observations, student interviews, and field notes. The videos produced by students functioned both as learning artifacts and as data sources. These videos captured what students perceived as important in the environment and how they visually represented ecosystem concepts. Classroom observations were conducted throughout the project using a semi-structured observation protocol focusing on student engagement, inquiry behaviors, collaboration, and expressions of critical thinking during learning activities and presentations.

Data analysis followed an iterative thematic approach (Braun & Clarke, 2006). All data were organized, coded, and analyzed through repeated reading and viewing. Video data were examined through analytic memos and selective transcription of segments reflecting observational practices and reasoning processes. Coding was guided by Facione's (2008) critical thinking framework—interpretation, analysis, inference, evaluation, and

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explanation—which informed categorization of students' reasoning across inquiry phases. Codes were grouped into broader themes representing patterns of environmental observation, reasoning processes, and modes of meaning construction.

Trustworthiness was enhanced through data triangulation, prolonged engagement, and member checking with the classroom teacher. Thick description was provided to support transferability, while dependability and confirmability were strengthened through documentation of research decisions and analytic procedures (Ahmed, 2024). Ethical approval was obtained from school authorities, and parental consent and student assent were secured prior to data collection.

Results and Discussion

This section presents the research findings based on a thematic analysis of data collected from student observation videos, classroom observations, group discussions, student interviews, teacher interviews, and the researcher's field notes. The emerging themes reflect how inquiry-based science learning, implemented through a video-based environmental observation project at Lake Tondano, contributed to the development of elementary students' understanding of ecosystems and their critical thinking skills. Table 1 summarizes the key themes identified through the thematic analysis and illustrates how students' critical thinking was evidenced across multiple data sources.

Table 1. Video-Based Inquiry Cognitive Development Model.

	Main Theme	**Data Sources**	**Indicators of Critical Thinking**	**Illustrative Data Evidence**
1	Identification of Components	Student videos, interviews, classroom observations	Identification, concept clarification	"In this lake, there are fish, aquatic plants, and water,..."
2	Interpretation of Conditions	Videos, presentations, classroom discussions	Interpretation, analysis	"The water is murky because of plastic waste…"
3	Causal Explanation	Discussions, student interviews	Cause–effect reasoning	If people throw garbage away, the fish can die…"
4	Collaborative Meaning-Making	Classroom observations, field notes	Argumentation, evaluation	Group discussions when selecting video scenes
5	Environmental Responsibility	Student interviews, presentations	Application, reflection	"We need to take care of the lake so it stays clean."
6	Inquiry Questioning	Classroom discussions	Questioning, inquiry	"Why are aquatic plants more abundant in shallow water?"
7	Reflection & Metacognition	Student interviews	Metacognition / reflective thinking	"I pay more attention to the lake now."

Table 1 illustrates the conceptual model emerging from the findings. The learning process began with direct observation of ecosystem components, which enabled students to identify and categorize biotic and abiotic elements (Theme 1). This foundational identification supported students in interpreting environmental conditions (Theme 2), which subsequently enabled the development of causal explanations (Theme 3). Collaborative

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dialogue (Theme 4) functioned as a mediating process that strengthened argumentation and conceptual refinement. The emergence of inquiry-oriented questions (Theme 6) and reflective awareness through video review (Theme 7) further deepened students' reasoning processes. Ultimately, this interconnected cognitive flow contributed to the development of environmental responsibility (Theme 5). The model demonstrates that environmental awareness did not emerge instantaneously, but evolved through iterative cycles of observation, representation, interpretation, dialogue, and reflection.

1) Recognizing Ecosystem Components through Direct Observation

The analysis indicates that students were able to identify biotic and abiotic components of the lake ecosystem in a more concrete manner through direct observation activities documented via video. In the videos they produced, students explicitly recorded and mentioned the presence of biotic components such as fish, aquatic plants, and birds, as well as abiotic components including water, soil, and sunlight. Importantly, students also began to position these components as parts of an interconnected ecological system rather than as isolated elements.

One student stated, *"In this lake there are fish, aquatic plants, and water. They are all connected so the lake can stay alive."* This finding suggests that the integration of direct observation and video documentation functioned as a cognitive scaffold, enabling students to transform ecosystem concepts from declarative knowledge into understanding grounded in empirical experience. The processes of recording and interpreting observations encouraged students to organize environmental information in a more structured way that reflects authentic engagement with phenomena. Constructivist perspectives in science education emphasize that learners actively construct knowledge through interaction with real phenomena and reflection on experience rather than passive reception of information (Taber, 2022). Consistent with this view, a recent systematic literature review by Dah et al. (2024) demonstrates that inquiry-based science learning, particularly open inquiry, supports deeper conceptual understanding and higher-order thinking by engaging students in authentic scientific practices, such as observation, interpretation, and explanation of real-world phenomena. In elementary science contexts, meaningful engagement with authentic environments—such as ecosystem observation—enables students to connect firsthand experiences with scientific concepts, thereby refining their conceptual understanding and strengthening critical thinking processes (Crawford et al., 2023). Together, these findings affirm that constructivist and inquiry-oriented learning experiences grounded in real contexts facilitate deeper understanding and promote students' active sense-making in science learning. This foundational identification of ecosystem components served as the initial cognitive anchor for subsequent interpretive and explanatory reasoning.

2) Interpreting Environmental Conditions within the Local Ecosystem

Building upon students' ability to identify ecosystem components (Theme 1), the second theme reflects students' ability to interpret environmental conditions of the lake, particularly related to water quality and the impacts of human activity. Several student videos deliberately highlighted differences in water color, the presence of waste, and community activities along the lakeshore. During one presentation, a student explained, *"The water here looks murky because there is a lot of plastic waste. If this continues, the fish can die."*

This statement indicates that students moved beyond simple observation to linking environmental conditions with their consequences for living organisms. These findings support the work of Ke et al. (2021), who argue that science learning grounded in real-life contexts enhances scientific literacy, particularly students' ability to interpret environmental phenomena. In this study, Lake Tondano functioned as a natural laboratory that facilitated

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contextualized meaning-making of ecosystem concepts. This interpretive stage marked a shift from descriptive recognition toward analytical reasoning, laying the groundwork for causal explanation.

3) Developing Causal Explanations from Concrete Phenomena

Following identification and interpretation (Themes 1 and 2), data analysis revealed the emergence of cause–effect reasoning among students. This pattern developed because students not only observed phenomena but also recorded, selected, and explained their own visual evidence, thereby activating critical thinking through reflection and argumentation. During classroom discussions and video presentations, students actively connected human activities to changes in water quality and the sustainability of living organisms. One student remarked, *"If people throw trash into the lake, the water becomes dirty, and then fish cannot survive. That's why there are fewer fish here."*

These findings indicate that inquiry-based video projects facilitated evidence-based reasoning, as students constructed causal explanations grounded in visual evidence they personally observed. Such reasoning emerged because students were actively involved in observing, selecting evidence, and articulating cause–effect relationships, rather than memorizing explanations provided by the teacher. The ability to construct causal explanations is a key indicator of critical thinking within scientific literacy (OECD, 2019).

These results are consistent with recent studies showing that inquiry-based science learning supported by student-generated data and open-ended questioning enhances students' causal reasoning and explanatory depth. For example, Lazonder and Harmsen (2023) report that inquiry learning environments that engage students in generating and interpreting their own evidence significantly promote causal understanding and scientific reasoning. Similarly, Zion and Mendelovici (2020) emphasize that open inquiry approaches encourage learners to formulate explanations based on observed evidence, thereby strengthening higher-order thinking and epistemic agency in science learning. Through video-based inquiry projects, students in this study became active constructors of scientific explanations rather than passive recipients of information. The progression from observation to interpretation enabled students to construct explanations grounded in evidence rather than speculation, indicating a deeper level of scientific reasoning.

4) Collaborative Construction of Scientific Meaning

Another prominent theme concerns the collaborative processes embedded in learning activities. During video production and editing, students engaged in group discussions to select scenes, agree on explanations, and interpret observational findings collectively. Field notes documented that "students engaged in intensive discussions to determine which video segments best represented the balance of the lake ecosystem."

This collaboration enabled students to negotiate meaning and strengthen conceptual understanding through social interaction. These findings are consistent with social constructivist learning theories, which emphasize the role of dialogue and collaboration in the construction of scientific knowledge (Vygotsky, as cited in Collado et al., 2020). Within the context of scientific literacy, collaboration supported students in articulating arguments, listening to alternative perspectives, and refining their understanding. Thus, collaboration functioned as a mediating mechanism that refined and stabilized emerging scientific explanations.

5) Connecting Scientific Concepts with Environmental Responsibility

Environmental awareness in this study therefore emerged as the culmination of prior cognitive processes rather than as an isolated attitudinal outcome. The findings also indicate that students began to link ecosystem concepts with attitudes of environmental responsibility.

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Several students explicitly proposed actions or solutions to protect the lake. One student stated, *"If we want the lake to stay clean, we must throw trash in the proper place and use water wisely."*

This finding suggests that science learning influenced not only students' cognitive understanding but also their environmental awareness and attitudes. Recent studies in environmental education demonstrate that direct, experience-based engagement with local natural environments significantly contributes to the development of pro-environmental attitudes, responsibility, and environmentally ethical behavior among elementary school students (Ardoin et al., 2023; Zhao et al., 2024). Such findings reinforce the view that contextual and inquiry-oriented environmental learning enables young learners to internalize environmental responsibility through meaningful interaction with real ecosystems, rather than through abstract instruction alone.

6) Emergence of Inquiry-Oriented Questions

Another salient theme was the emergence of inquiry-based questions during student presentations and classroom discussions. Students did not merely report their observations but also posed critical questions to their peers. One example included the question, *"Why are aquatic plants more abundant in the shallow parts of the lake?"* Such questions reflect a shift in students' roles from passive recipients of information to active inquirers who engage in sense-making through questioning. Recent research in elementary science education indicates that student-generated questions are a key indicator of developing scientific literacy and inquiry competence, as they demonstrate curiosity, reasoning, and an emerging capacity to frame scientific problems (Kang & Keinonen, 2018; Dah et al., 2023). Compared to traditional teacher-centered instruction, inquiry-oriented learning environments provide greater opportunities for students to cultivate scientific curiosity, questioning skills, and reflective thinking through dialogue and peer interaction.

7) Enhancing Reflective Awareness through Video-Based Observation

Student interviews revealed that the video-making process fostered reflection and heightened awareness of the surrounding environment. Students reported that recording and reviewing observations prompted them to notice environmental details that previously went unnoticed. One student explained, "Usually I just pass by the lake, but when making the video, I paid more attention." These findings indicate that video functioned not only as a documentation tool but also as a metacognitive tool that facilitated reflection on learning processes and observational experiences. By reviewing their video recordings, students had opportunities to reassess observations, deepen understanding, and become aware of shifts in their thinking about the environment. This finding extends the work of Chang and Hwang (2018) by demonstrating that enhanced visual learning does not necessarily require advanced technologies such as augmented reality. Simple, contextually grounded video production based on local environments can effectively support reflection and critical thinking development among elementary students.

Overall, the cross-theme findings indicate that students' critical thinking and scientific literacy developed through interconnected cognitive mechanisms grounded in authentic environmental engagement. While this study was situated in the local ecosystem of Lake Tondano, the patterns observed reflect broader global environmental challenges, including water pollution, biodiversity decline, and unsustainable human practices that affect freshwater systems worldwide. By engaging students in direct observation, video-based documentation, collaborative reasoning, and reflective dialogue, the learning process enabled them to connect local ecological realities with wider environmental concerns. This suggests that inquiry-oriented, contextually grounded science learning can serve as a scalable

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pedagogical approach for fostering environmental awareness and critical thinking in diverse international contexts facing similar ecological issues.

Conclusion

This study shows that inquiry-based learning through environmental video observation projects offers a meaningful pedagogical approach for fostering elementary students' critical thinking. Engagement with the Lake Tondano ecosystem enabled students to develop conceptual understanding while constructing scientific meaning grounded in authentic and contextually relevant experiences. The findings indicate that critical thinking can be effectively supported when science learning is designed around inquiry processes and utilizes the local environment as a primary learning resource.

The processes of observation, video documentation, and classroom presentation encouraged students to analyze cause–effect relationships, evaluate evidence, and reflect on environmental sustainability. Theoretically, this study contributes to situated learning and multimodal inquiry perspectives by demonstrating the role of student-generated visual representations in meaning-making. Practically, the findings provide empirical support for the contextual implementation of inquiry-based, video-supported environmental learning in elementary science classrooms. Overall, the study highlights the importance of moving beyond transmissive instruction toward inquiry-oriented and reflective science learning that promotes both critical thinking and environmental responsibility.

Recommendation

Based on the findings of this study, several recommendations can be proposed for future research and the development of science teaching practices. Future studies are encouraged to extend this model to different ecological contexts—such as coastal areas, forests, rivers, or urban environments—to examine how varying environmental characteristics shape inquiry processes and the development of elementary students' critical thinking. Employing mixed-methods designs that combine qualitative analysis with quantitative measures of critical thinking or scientific literacy may also provide a more comprehensive understanding of the impact of environmental project-based learning.

In addition, curriculum integration should be strengthened by explicitly embedding video-based environmental observation projects within science units on ecosystems, sustainability, and human–environment interaction. Policymakers and curriculum developers are encouraged to incorporate student-generated content (SGC) approaches into local science curriculum guidelines, ensuring alignment between environmental issues in the community and classroom learning objectives. School principals can support implementation by facilitating teacher professional development, allocating time for project-based inquiry, and providing basic digital infrastructure that enables student documentation and presentation.

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