

Integrating Water Sustainability into Primary Science Education: Teachers' Pedagogical Rationales, Opportunities, and Barriers

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Abstract

Water sustainability is a key global concern highlighted in SDG 6 (Clean Water and Sanitation). Integrating this topic into primary science education is strategic for fostering scientific literacy, environmental awareness, and responsible values from an early age. This study explores primary school teachers' pedagogical perspectives on the importance of water sustainability, opportunities for integration, and perceived barriers to classroom implementation. A qualitative descriptive approach was employed using an open-ended online questionnaire completed by 141 primary school teachers across Indonesia. The data were analyzed thematically using NVivo. The findings reveal five rationales for integration: environmental awareness, science literacy, character and values education, alignment with the SDGs, and relevance to students' daily lives. Teachers identified integration opportunities through science topics, environmentally themed learning, and project-based activities. However, teachers anticipated barriers including limited resources, low confidence, dense curriculum demands, time constraints, local environmental conditions, and challenges in selecting appropriate instructional methods. The novelty of this study lies in examining primary school teachers' pedagogical reasoning regarding water sustainability and identifying opportunities and barriers to its integration into science learning. The findings suggest that the integration of water sustainability is influenced by curriculum demands, teacher preparedness, available resources, and local environmental conditions. This study contributes to sustainability education research by providing insights into how sustainability goals are interpreted and implemented in primary school contexts.

Keywords:

Primary science education; Water sustainability; Teachers' pedagogical reasoning; Sustainability education; Science education.

Introduction

Water and its sustainability have become crucial issues in global development. Sustainable Development Goal (SDG) 6, clean water and sanitation, explicitly addresses water management and access. Water is also intrinsically linked to several other SDGs, such as SDG 3 (Good Health



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and Well-being), SDG 13 (Climate Action), SDG 14–15 (Life Below Water and Life on Land), as well as socio-economic issues, including poverty and food security. This highlights that water is a cross-cutting theme within sustainability development frameworks. Water sustainability refers to the conservation and equitable accessibility of clean water to support human consumption, agricultural practices, and biodiversity for future generations (Haque et al., 2025; Ramírez-Segado et al., 2025).

In the context of primary education, integrating water sustainability topics is a strategic step to foster sustainability awareness from an early age and to develop environmentally responsible citizens. Various studies have shown that the primary school age is a crucial period for shaping students' values, attitudes, and environmental awareness (Irimia et al., 2025; Praveena & Themudu, 2022; Ruiz-Garzón et al., 2021). Recent studies have demonstrated that teaching these topics in primary school can help students comprehend the intricate relationships between human needs, the environment, and public policy (Pozo-Muñoz et al., 2023; Tsiaras & Chavenetidou, 2024).

The urgency of teaching water sustainability is particularly relevant in Indonesia, as water remains a pressing environmental and social issue. National environmental reports indicate that it is facing increasing water-related challenges. The Minister of Environment and Forestry, Republic of Indonesia (2023), reports that river water quality in many regions does not meet established standards, with biological oxygen demand (BOD), chemical oxygen demand (COD), fecal coliform, and total coliform levels exceeding permissible thresholds in most provinces due to domestic pollution. BPS-Statistics Indonesia (2025) also reported disparities in household access to safe drinking water between regions, with provinces such as Papua and Bengkulu having lower levels of access compared to the national average. These conditions highlight the importance of integrating water-related sustainability issues into primary science education to foster environmental awareness and responsible citizenship among young learners.

In this context, water sustainability is more than an environmental or moral concern (Blom & Karrow, 2024). It provides a meaningful context for developing water awareness. Awareness of water sustainability cannot be developed solely through cognitive learning, but needs to be embedded in learning experiences that encourage critical reflection, empathy, and active engagement with real-world problems (Mostacedo-Marasovic et al., 2022). Teachers are central to this process because they guide students in interpreting water-related sustainability issues through scientific reasoning. Consequently, teachers' beliefs,

perspectives, and preparedness strongly influence how these topics are addressed in classroom practice (Boon, 2024).

However, integrating water sustainability into science learning is not a simple task. Teachers' capacity to integrate these topics is influenced by their pedagogical content knowledge, confidence, and access to contextual teaching resources (Forsler et al., 2024). Many teachers still struggle to translate broad sustainability goals into classroom practices that are appropriate to students' age and characteristics, particularly when curricular guidance and professional preparation remain limited (Forsler et al., 2025; Uygun & Bayrakci, 2025). For this reason, it is important to examine how teachers perceive the urgency of water sustainability, as well as the opportunities and challenges they encounter when integrating it into science learning.

Theoretical framework

This research is based on the perspectives of ecopedagogy and Education for Sustainable Development (ESD). Ecopedagogy views education as a space for building ecological awareness, ethical responsibility, and a critical understanding of the relationship between humans and the natural environment (Kahn, 2010; Misiaszek, 2015). From this perspective, water sustainability is viewed as both a scientific topic on natural resources and an ecological, social, and pedagogical issue. Ecopedagogy emphasizes the importance of helping students critically understand how everyday human activities are connected to water sustainability. This perspective aligns with the goals of ESD, which emphasize that education should be oriented toward mastering knowledge, developing values, attitudes, and actions that support sustainable living (UNESCO, 2020).

In the context of primary science education, the issue of water provides a learning context closely related to students' everyday experiences. Topics such as water use, environmental cleanliness, the water cycle, natural resources, pollution, and conservation help students connect scientific concepts to the realities of their surroundings. Therefore, science learning oriented toward water sustainability can foster awareness, responsibility, and critical reflection on environmental issues that impact human life and ecosystems (Cabarcas-Fuentes & Rodríguez-Chueca, 2026; McCarroll & Hamann, 2020).

This study uses the concept of teachers' pedagogical reasoning as the basis for analysis. Pedagogical reasoning refers to the professional process of teachers in understanding material, transforming it into a teachable form, selecting appropriate learning strategies, and considering student characteristics and the learning context (Elliott, 1996; Shulman,

1987). Within this framework, teachers' pedagogical reasoning is used to analyze how primary school teachers interpret water sustainability as a learning issue, provide pedagogical reasons for integrating it into science learning, and identify opportunities and barriers to classroom implementation. By integrating perspectives from ecopedagogy, ESD, and teachers' pedagogical reasoning, this study views water sustainability education as both a scientific and a pedagogical issue.

Although ESD and SDG 6 have been widely emphasized in global education research, empirical studies focusing on primary school teachers' perceptions of water sustainability remain limited. In Indonesia, although there is no national education policy or school curriculum that explicitly addresses water sustainability at the primary level, the broader direction of education policy provides space for integrating environmental and sustainability issues. This is reflected in the emphasis on scientific literacy, character education, and contextual learning using real-world issues. These policy orientations align with the principles of ESD and support the integration of global sustainability goals into national educational practice. Within this framework, water sustainability can be positioned as a relevant topic in primary education, with teachers playing a key role in translating global goals into classroom practice.

Most existing studies on water sustainability education have focused on students' understanding of water-related issues (Pozo-Muñoz et al., 2023; Ramírez-Segado et al., 2021; Zhan et al., 2019), the development of sustainability-related competencies and skills (García et al., 2025; Pozo-Muñoz et al., 2023; Rey et al., 2022; Tsiaras & Chavenetidou, 2024) and instructional strategies (Imaduddin & Eilks, 2024; Scarborough et al., 2022; Stephenson Reaves, 2023). In contrast, teachers' pedagogical reasoning, contextual interpretations, and challenges in implementing water sustainability have received far less attention. This gap is important because teachers play a central role in translating sustainability goals into meaningful learning experiences through their selection of teaching materials, instructional approaches, and the integration of contextual environmental issues into primary science classrooms (Green & Somerville, 2015; Inoue et al., 2016; Kwee & Dos Santos, 2023). Without understanding teachers' pedagogical reasoning, it remains difficult to explain how water sustainability can be meaningfully and realistically integrated into primary science classrooms.

Furthermore, most prior research was conducted in Western or secondary education contexts. This leaves a knowledge gap regarding how teachers in developing countries, particularly in Indonesia, conceptualize and integrate water sustainability in classroom teaching.

Unlike previous studies that primarily emphasized student outcomes and instructional approaches, this study examines primary school teachers' pedagogical reasoning, perceived opportunities, and obstacles in teaching water sustainability. These findings provide insights to inform sustainability-oriented pedagogy and teacher education programs at the primary level.

This study aims to explore primary school teachers' pedagogical perspectives on integrating water sustainability into primary science education, including their perceptions of its importance, the opportunities they identify for integration, and the barriers they anticipate in classroom implementation. Therefore, this study was guided by the following research questions:

1. How do primary school teachers perceive the importance of integrating water sustainability into primary science education?
2. What opportunities do primary school teachers identify in integrating water sustainability into primary science learning?
3. What barriers do primary school teachers anticipate in implementing water sustainability education in primary classroom practice?

Method

Research Design

This study employs a qualitative descriptive approach to explore primary school teachers' perspectives on water sustainability in primary science (Mackiewicz, 2018). This design was chosen because the study aimed to obtain a broad and practice-oriented understanding of teachers' rationales, perceived opportunities, and anticipated barriers, rather than to examine lived experiences in depth or analyze a bounded instructional setting.

Unlike phenomenological studies, which focus on the essence of individual experiences or case studies examining specific contexts or cases, a qualitative descriptive approach was considered more appropriate for capturing diverse perspectives across teachers from different regions. The use of an open-ended online questionnaire further supported this aim by enabling the collection of varied reflections from a wider participant pool, aligned with the exploratory nature of the research questions. The use of written open-ended responses allowed participants to explain their experiences and perspectives in their own words and at their own pace. The online format also enabled teachers from different geographical regions to participate, supporting the exploratory aim of capturing varied pedagogical perspectives on water sustainability.

Participants

Participants included 141 primary school teachers (33 male and 108 female) from diverse regions across Indonesia. Teachers were recruited using voluntary response sampling through an open online invitation distributed via accessible professional teacher networks. This sampling approach was convenience-based rather than purposive, as participation depended on teachers' self-selection. While this strategy enabled broad geographical coverage, it may have favored teachers with a greater interest in sustainability-related topics. To broaden participation, the invitation was disseminated across multiple teacher communities representing different regions and socio-economic contexts.

Table 1.
Demographic characteristics of participants

Characteristic	Category	n
Gender	Male	33
	Female	108
Teaching experience	1–5 years	60
	6–10 years	42
	years	22
	>15 years	17
Region of employment	Java	42
	Sumatra	30
	Kalimantan	31
	Eastern Indonesia	38
School type	Public primary school	98
	Private primary school	43

Table 1 presents the demographic characteristics of the participants. In this study, Eastern Indonesia refers to provinces in Sulawesi, Nusa Tenggara, Maluku, and Papua. Given the sampling strategy and study aims, the findings are intended to provide exploratory insights into teachers' rationales, perceived opportunities, and barriers rather than to represent the broader teacher population. Although the study relied on open-ended online responses, many participants provided relatively detailed explanations and reflections regarding water sustainability in primary science education. Responses from teachers across different regions showed recurring patterns and variations in perspectives, which contributed to the development of themes during the analysis. This diversity of responses supported the study's exploratory aim of capturing a broad range of teachers' pedagogical perspectives.

Data Collection

The open-ended questionnaire was developed based on the study's research focus and the concept of teachers' pedagogical reasoning, particularly teachers' considerations regarding instructional goals, classroom integration and contextual challenges in

teaching water sustainability. The questionnaire was then organized into three main sections: (1) teachers' views on the importance and rationale for teaching water sustainability in primary schools; (2) perceived opportunities for integrating the topic into science learning; and (3) anticipated obstacles or challenges in implementation.

To ensure the instrument's content validity and clarity, the initial draft was reviewed by two experts in science education and sustainability. Their feedback led to minor revisions in wording and sequencing to improve contextual relevance. The revised questionnaire was piloted with six teachers from a primary school, and further refinements were made based on their feedback to improve clarity and comprehensibility.

The open-ended online questionnaire was distributed electronically and remained accessible for four weeks (February–March 2025). Before completing the questionnaire, participants were informed of the study's purpose, the voluntary nature of participation, and their right to withdraw at any time. Informed consent was obtained electronically prior to participation. No personally identifiable information was collected, and participants' responses were anonymized during analysis. All data were stored securely and were accessible only to the research team. Because the study involved voluntary participation, anonymous responses, and no sensitive personal data, formal ethical approval was not required under institutional research guidelines.

The questionnaire consisted of open-ended questions designed to elicit teachers' perspectives on water sustainability. Example items included: (1) Why do you think water sustainability is important to be taught in primary school? (2) In what ways do you see opportunities to integrate water sustainability into primary school learning? (3) What challenges do you anticipate when implementing water sustainability topics in your classroom?

Data Analysis

Qualitative responses were analyzed using thematic analysis following Braun and Clarke's six-phase framework (Braun & Clarke, 2006). The analysis also drew on later developments in reflexive thematic analysis that emphasize the interpretive role of researchers in theme construction (Braun et al., 2022). Coding was conducted primarily inductively, meaning that themes were developed from participants' responses while still being guided by the study's focus on teachers' pedagogical reasoning. The analysis focused mainly on semantic themes, emphasizing participants' explicit perspectives and explanations regarding water sustainability in primary science education. All responses were read several times to develop familiarity with the data. Initial open coding

was used to identify recurring ideas, rationales, and perceptions. Codes were then reviewed, refined, and grouped into broader themes through an iterative process of comparison and interpretation. Theme development continued through iterative comparison and refinement until the themes adequately represented recurring patterns in the dataset. A single response could be assigned multiple codes when it reflected more than one idea or perspective. NVivo software was used to organize responses, manage coding categories, retrieve coded excerpts, and facilitate comparisons during theme development and refinement. The findings section presents representative excerpts and coding categories to illustrate how themes were developed from participants' responses and to enhance analytical transparency. Additional examples of the coding and theme development process are also provided in Appendix A.

To enhance credibility and trustworthiness, the coding process involved the first researcher and three additional researchers with experience in science education and qualitative research. After the first researcher completed initial open coding, the coding results and emerging themes were collaboratively reviewed through a series of peer debriefing discussions. During these discussions, differences in interpretation were examined by revisiting participants' responses, comparing coding rationales, and refining theme boundaries until agreement was reached. An audit trail was maintained throughout the analytical process by documenting coding revisions, theme development procedures, analytical notes, and interpretive decisions. In addition, member checking was conducted with six participants, who were asked to review summaries of the preliminary themes to verify whether the interpretations accurately reflected their perspectives. Reflexive memos were also written throughout the analysis to monitor researchers' assumptions, interpretive decisions, and potential biases. The research team's background in science education and sustainability-related research informed the study's interest in exploring teachers' perspectives on water sustainability. Throughout the analysis, the research team remained aware of the potential influence of these perspectives on data interpretation and addressed potential biases through reflexive discussions and memo writing. These procedures helped strengthen the credibility, dependability, and confirmability of the findings.

Findings

Primary Teachers' Pedagogical Rationales for Integrating Water Sustainability into Primary Science Education

This study reveals the various reasons primary school teachers cite for integrating water sustainability issues

into primary school science learning. Based on the results of the thematic analysis, five main themes were obtained that reflect the participants' thinking frameworks. Each theme is supported by narrative quotes and frequency data that demonstrate the strength of representation for each reason, as provided in Table 2 below.

Table 2 presents the themes and codes related to teachers' rationales for integrating water sustainability in primary science. In this study, frequency counts (f) indicate the recurrence of specific codes within each theme and are used to illustrate the relative prominence of themes in the dataset, rather than to quantify responses at the theme level.

The first theme emerging from teachers' responses was raising environmental awareness. Teachers viewed the introduction of water sustainability issues from an early age as important for helping students develop awareness of the need to protect water resources. Their responses also linked water sustainability learning with everyday habits, such as using water wisely and caring for the environment from an early age. Many teachers emphasized the importance of nurturing a generation that is more environmentally aware through learning activities connected to students' daily lives.

Another theme concerned the relationship between water sustainability and the SDGs, particularly issues related to clean water access and sustainable water resources. Teachers recognized that water issues extend beyond the science content taught in the classroom. Many teachers also viewed water-related learning as a way to introduce students to broader environmental issues. This suggests that many teachers were already concerned about future environmental sustainability. Teachers also viewed water sustainability as part of character and values education. In their responses, water-related issues were often associated with developing habits of wise water use, gratitude for natural resources, and responsibility toward the environment. Teachers also connected water sustainability learning with the development of students' everyday attitudes and habits.

In addition, relevance to daily life emerged as one of the reasons why this topic was considered suitable for primary science learning. Teachers referred to students' routine activities, such as bathing, washing, drinking, and watering plants, as contexts closely related to their everyday experiences. This connection to daily activities made water sustainability easier for students to understand because it was closely linked to situations they encounter in everyday life. The final theme related to strengthening scientific literacy. Teachers viewed water as an important concept for understanding its relationship with living things and

the environment. Teachers also considered water sustainability helpful for introducing science concepts related to the environment and daily life.

Primary Teachers' Perceived Opportunities for Integrating Water Sustainability into Primary Science Education

Teachers described various opportunities for integrating water sustainability into primary school learning. Their responses showed that water sustainability could be connected to science topics, environmental themes across subjects, and contextual learning activities. An overview of the main themes identified from participants' responses is presented in Table 3.

The most frequently mentioned opportunity concerned integrating water sustainability into existing primary science topics across grade levels. Teachers commonly associate water sustainability with topics such as ecosystems, natural resources, environmental change, and daily life contexts. Several participants also described more specific examples of how water sustainability could be integrated into science learning from Grades 1 to 6. Representative examples provided by teachers are presented in Table 4.

The examples presented in Table 4 illustrate how teachers connected water sustainability with science

topics across different grade levels. These responses suggest that teachers viewed water sustainability as relevant to a wide range of primary science contexts and everyday environmental issues.

The second opportunity identified from teachers' responses was the integration of water sustainability through environmental themes across subjects. Teachers associated water sustainability with environmental topics discussed in several school subjects, such as citizenship education, language learning, mathematics, arts, and social science. Examples provided by teachers are presented in Table 5.

The examples in Table 5 illustrate that teachers associated water sustainability with environmental themes across different subjects. Water-related issues were linked with topics such as environmental responsibility, natural resources, and environmental change in various learning areas.

The third opportunity identified from teachers' responses was the integration of water sustainability through thematic or end-of-semester projects. Teachers described project activities as opportunities for students to explore water-related issues in more contextual ways. Representative examples provided by teachers are presented in Table 6.

Table 2.

Rationale for water sustainability in primary science

Theme	Code	Example statement	f
Raising environmental awareness	Early water awareness	It is very important because the earlier it is taught to children, the more they will understand the importance of water for the sustainability of life (T-5)	35
	Eco-conscious generation	Knowledge about the importance of water and how to save it from an early age will form good habits that will last into adulthood (T-25)	18
Alignment with SDGs	Availability of clean water	It is very important to teach this because children need to understand the importance of sustainable clean water (T-4)	6
	Water sustainability	Water sustainability is very important for primary school students because it is for life now and in the future (T-6)	19
Character and values education	Good and being grateful	So that students really know the benefits of using water and continue to be grateful (T-1)	1
	Use water wisely	It is very important that children understand how to use water wisely (T-14)	23
	Build positive character	Develop good habits in using water (T-8)	9
	Environmental stewardship	Students can become more environmentally conscious and can help create a more sustainable future (T-13)	12
Relevance to daily life	Bathing	This topic is very relevant to their daily lives, like bathing.....(T-7)	8
	Drinking	...water is a basic necessity in daily life, such as for drinking, cooking, etc (T-3)	4
	Washing	Students must know how to maintain clean water that can be used daily, such as, washing clothes.....(T-15)	5
	Watering plants	Water is very necessary for humans in daily life, also for animals, and for watering plants (T-16)	2
Supporting science literacy	Water is a source of life	Because water is a source of life for living creatures, from the beginning of life until death (T-31)	43
	Importance of the ecosystem balance	Important to maintain the balance of the ecosystem (T-1)	9

Table 3.*Overview of teachers' perceived opportunities for integrating water sustainability into primary school learning*

Theme	Description	f
Integration into primary science topics	Water sustainability can be integrated into science topics from Grades 1–6	111
Cross-subject integration through environmental themes	Water sustainability can be connected with environmental themes across subjects	25
Integration through thematic projects	Water sustainability can be integrated through thematic or end-of-semester projects	10

Table 4.*Representative examples of water sustainability integration across primary science topics*

Grade	Primary Science Topic	Example Statement
I	Natural events	"...in the theme of introducing natural disasters such as floods and droughts..." (T-99)
II	Clean and healthy environment	"The topic of water sustainability is very flexible and can be integrated into various science lesson themes, including the theme Clean and Healthy Environment (Grade 2 Primary School)" (T-39)
III	Ecosystem	"This topic is integrated with the material on the water cycle, natural resources, and ecosystems" (T-42)
IV	Natural resources and environment	"Science: Natural Resources. Because it also includes how to utilize natural resources, including the water cycle" (T-25)
V	Harmony in the ecosystem	"The role of water in maintaining ecosystem balance and the impact of water pollution (grade 5)" (T-67)
VI	Our Earth is in danger	"For grade 6, the topic can be connected with the chapter 'Our Earth is Threatened with Danger'" (T-26)

Table 5.*Examples of water sustainability integration through environmental themes across subjects*

Subjects	Environmental theme	Example statement
Pancasila and civic education	Citizens' responsibility in protecting natural resources	Activity: Discussion of rights and obligations in water use (T-67)
Indonesian language	Write an appeal text, create a poem, or a story (about the importance of water)	Making water-saving campaign posters, composing speeches about water (T-81)
Mathematics	Calculating volume (of liquids)	The project records daily water usage at home (T-92)
Arts, Culture and Crafts	Creating artwork illustrating water conservation messages (comparisons of clean and polluted rivers, or campaigns encouraging responsible water use).	Painting about clean and polluted rivers (T-94)
Social science	Sustainable development, environmental change	Discuss the social impacts of water shortages or water management (T-49)

Table 6.*Examples of water sustainability integration through thematic projects*

Project Activity	Example Statement
Water-saving campaign project	"Students are asked to make posters about keeping water, rivers, and the sea clean" (T-81)
Observation of water use in daily life	"Students keep a simple weekly record of how they use water wisely at home and at school during the semester" (T-55)
Environmental cleanliness project	"Students can join activities such as cleaning rivers, water springs, or nearby wetlands" (T-67)

The examples in Table 6 suggest that teachers preferred simple, contextually relevant project activities closely related to students' daily lives and local environments.

Teachers also identified opportunities to integrate water sustainability into learning methods and approaches suitable for primary science learning. Many teachers emphasized hands-on activities, such as observing water use in daily life, visiting nearby water sources, and creating simple tools related to water recycling. Other responses highlighted the use of simple experiments, including water filtration and evaporation activities. Teachers viewed these activities as helpful for understanding science concepts through direct experience. They also mentioned using videos and picture stories, particularly for lower-grade students. These media were considered helpful for explaining environmental issues in more engaging ways. In addition, classroom discussions were viewed as opportunities for students to share experiences and express their opinions about water-related issues. Several teachers also referred to project-based learning, problem-based learning, and contextual learning approaches. These responses suggest that teachers preferred learning activities closely connected to students' everyday experiences and surroundings.

Primary Teachers' Perceived Barriers to Integrating Water Sustainability into Primary Science Education

Based on primary school teachers' perceptions of the obstacles they might encounter when integrating water sustainability into science learning, six relevant themes were identified, as presented in Table 7.

In this table, the frequency (f) represents the number of teachers who mentioned each obstacle theme in their responses, indicating the relative prominence of obstacles across participants. The obstacles described above arise from various internal and external factors that can influence the effectiveness of integrating water sustainability into science learning in primary schools.

The first theme that emerged from the teachers' responses related to limited school facilities and resources. Teachers cited a lack of learning media, limited laboratories, and limited facilities for environmental observation as obstacles to teaching water sustainability. Some teachers felt that learning about water would be easier for students to understand if supported by practical activities or direct observation. However, school conditions did not always allow for this. One teacher explained that their school "did not yet have sufficient facilities to support direct environmental observation activities" (T-9). This response indicates that some teachers still view water sustainability as material that requires special learning facilities, adequate media or specific practical activities to facilitate student understanding.

Teachers also mentioned limited understanding and confidence in integrating water sustainability issues into science lessons. Several responses indicated that teachers still struggle to grasp the concept of water sustainability in depth and connect it to primary school learning materials. One teacher stated that "the concept of water sustainability is still quite difficult to explain to primary school students" (T-24). Furthermore, some teachers also found it difficult to explain the topic in a way that was simple, engaging, and appropriate to the characteristics of primary school students. Teacher responses indicated that they were still confused about how to explain water sustainability issues in a way that aligns with primary school students' understanding.

Another frequently encountered obstacle relates to curriculum limitations and learning time. Teachers described how the dense learning materials and demands to meet curriculum targets limited their time for in-depth discussion of additional topics, such as water sustainability. Some teachers also expressed hesitation in integrating the topic due to a lack of clear emphasis in the curriculum documents. One teacher stated that "there is already quite a lot of material to cover in school, making it difficult to add in-depth discussion" (T-11). This response indicates that some teachers still view water sustainability as an additional topic outside of the core material to be covered in class.

Table 7.

Obstacles to integrating water sustainability into science learning in primary schools

Theme	f	Statement example
Limited resources and facilities	66	Lack of supporting facilities at school (T-7)
Limited teacher knowledge and confidence	26	Lack of in-depth understanding of the concept of water sustainability among teachers (T-5)
Curriculum constraints	25	Dense Curriculum Focus (T-4)
Environmental context	25	Students tend to underestimate the benefits of water because there is an abundance of water at home (T-30)
Time limitation	20	limited learning time at school (T-16)
Method uses	18	The teacher has not been able to package the explanation regarding this topic to students in a good and interesting way, so that students can understand and accept the explanation from the teacher (T-70)

Teacher responses also demonstrated that environmental conditions influence how students perceive water sustainability issues. In some areas where students live, water is abundant, leading them to believe it will always be available. Teachers believe this makes students less aware of the importance of water conservation. One teacher explained that “students are accustomed to seeing water available in abundance, so they feel it will always be available” (T-81). In contrast, teachers in areas with sanitation issues or limited water resources described water issues as more closely related to students’ everyday experiences. This difference in context suggests that students’ environmental experiences shape how they understand water sustainability issues in their learning.

Furthermore, limited learning time presents a challenge in implementing more contextual learning. Teachers feel that activities such as projects, field observations, or discussions require more time than regular learning. Class hours in primary schools are relatively limited. Several teachers reported that school time is often insufficient to implement experiential learning activities. Teachers also reported difficulty selecting learning methods appropriate to students’ characteristics, classroom conditions, and school facilities. One teacher explained that they “seem to have difficulty explaining the topic of water sustainability in a way that is interesting and easy for students to understand” (T-78). Teacher responses indicate that they still struggle to adapt water sustainability learning to classroom conditions and the characteristics of primary school students.

Discussion

The findings of this study indicate that primary school teachers have diverse reasons for emphasizing the importance of integrating water sustainability into science learning. Teachers view water sustainability as a topic close to students’ daily lives, making it relevant for classroom learning. The emphasis on awareness and character building indicates that water sustainability is understood more as part of the development of students’ behavior and habits than as mastery of scientific concepts. Teachers also frequently link learning about water with wise water use, gratitude, and environmental responsibility. This emphasis on the formation of sustainable values, awareness, and behavior at the primary school level is also widely found in previous research (Echegoyen & Martín, 2021; Siraj & Pramling, 2016; Višnjić-Jevtić et al., 2022; Wang et al., 2024). This condition shows that sustainability learning at the primary school level is still more often positioned as a means of forming awareness and behavior rather than as a space to understand the complexity of sustainability issues in more depth (Calikusu & Sabanci, 2025)

Although teachers have linked water sustainability to the SDGs, this understanding tends to focus on the importance of clean water and the responsibility to protect the environment. Teachers have not yet linked water issues to other sustainability issues, such as health, climate change, or ecosystem sustainability. Yet, water issues are closely linked to various global sustainability issues (UN-Water, 2016). The SDGs are not yet fully understood as a learning framework that interconnects sustainability issues. Teachers still tend to understand the SDGs separately and unrelatedly. This finding supports previous research showing that teachers often struggle to understand and integrate the SDGs more holistically into their learning (Ampartzaki et al., 2021; Hashim, 2023; Imaduddin & Eilks, 2024). However, in the ESD concept, the SDGs are expected to serve as a basis for developing integrated learning strategies.

Teachers also identified concrete entry points for learning. They cited a variety of science topics from grades 1 to 6 as relevant contexts. This was possible because they believed that integrating water sustainability into core science themes was a meaningful form of learning (Tsiaras & Chavenetidou, 2024). Teachers view cross-subject integration and end-of-semester thematic projects as learning opportunities, for example through observing water use in students’ environments (T-39; T-67). This kind of cross-disciplinary approach has proven effective in preparing students to face complex and interconnected sustainability challenges, including those related to water (Romulo et al., 2024). In addition, integration into an end-of-semester thematic project with adequate time can increase student engagement, develop critical skills, and strengthen environmental awareness (Valenzuela-Morales et al., 2022; Yang, 2021). This project-based orientation is also supported by empirical evidence showing that sustainability-based water projects can be implemented through an inquiry-based approach. Simple, low-cost water purification activities are one example of a project context with limited resources (Fikri et al., 2026). The identified opportunities indicate that teachers are beginning to consider pedagogical factors in integrating water sustainability into learning.

Regarding implementation barriers, this study revealed a clear contradiction between awareness and implementation. On the one hand, teachers demonstrated strong awareness and clear pedagogical reasoning in integrating water sustainability into classroom learning. However, teachers also predicted classroom implementation barriers. Teachers’ awareness of the importance of water sustainability was not always accompanied by pedagogical readiness and structural support in schools. Teachers recognized that water sustainability issues were important to teach, but they still faced

limitations in translating these issues into practical learning practices. Various barriers stemmed from limited facilities and resources, including technology and costs (Espinoza-Ramos & Capucci-Polzin, 2025; Rosmiati et al., 2025), low teacher knowledge and confidence (Alsina & Vásquez, 2025), pressure from a dense curriculum and limited learning time (Do & Thinh, 2025), and the influence of environmental context on the perception of the urgency of water issues (Hamwy et al., 2023), also experienced by other teachers in implementing continuous learning. Difficulties in selecting appropriate learning methods also indicate the need for flexible time planning and adequate pedagogical support (Hamwy et al., 2023). This contradiction between intention and practice reflects the gap between teachers' normative commitments and their pedagogical capacities, as also reported in various international studies on sustainability education (Alsina & Vásquez, 2025).

In the context of Indonesian education, the contradiction between awareness and implementation needs to be understood as a structural issue. Thematic learning in character education offers opportunities to integrate water sustainability across subjects. However, this differs from several countries that have explicitly incorporated sustainability and the SDGs into science curriculum standards (Annamalai et al., 2025; Ferrer-Est & Chalmers, 2021), integration in Indonesia still relies heavily on teacher interpretation and initiative. Furthermore, local environmental conditions also influence perceptions of the urgency of water issues. In areas with abundant water, water sustainability is often seen as less pressing. In areas with limited water, however, the issue is more easily contextualized. This reliance on these factors can potentially lead to uneven integration practices across schools and contexts. As a result, water sustainability learning develops more based on local needs and experiences than through systematic planning. The interplay between structural constraints and social contexts means that water sustainability has not yet become a consistent framework in primary school learning. Without explicit curricular and pedagogical guidance, sustainability learning often relies on individual teachers and varies across schools (Vesterinen, 2024).

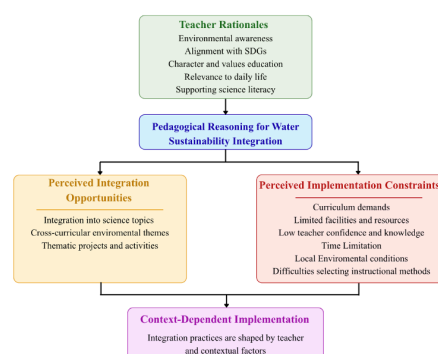
Water sustainability learning in Indonesia is also shaped by everyday practices and community values. Teachers often use domestic activities such as bathing, washing, and household water use as entry points for learning because they are close to students' lives. Water sustainability is not positioned as a scientific topic, but as a form of social and moral responsibility. This sociocultural context explains why teachers often link water sustainability learning with character education and attitude development rather than focusing solely on scientific concepts.

Overall, the research findings indicate that teachers view water sustainability as an issue close to students' daily lives and relevant to primary school learning. They emphasize the importance of environmental awareness and consider how water issues can be connected to science topics, learning projects, and classroom activities. However, these integration efforts are still constrained by various limitations, including curriculum, learning time, facilities, and teacher preparedness. As a result, the implementation of water sustainability learning varies among teachers and across school contexts. This research suggests that integrating water sustainability in primary schools depends on teacher awareness, pedagogical support, and the learning conditions within the school.

The findings also suggest that teachers' perspectives on water sustainability are shaped by environmental concerns and practical classroom considerations. Although teachers recognized the importance of water sustainability and identified various opportunities for integration, their implementation decisions were influenced by curriculum demands, available resources, student characteristics, and local environmental conditions. These findings indicate that integrating water sustainability into primary science learning involves balancing sustainability goals with the realities of classroom practice. This research also contributes to ESD studies. The findings suggest that teachers interpret water sustainability as an environmental topic and issue closely related to students' daily experiences, character development, and classroom learning practices. This indicates that sustainability integration in primary education is influenced by sustainability goals, teachers' pedagogical considerations and the realities of classroom contexts.

Based on the findings and discussion, Figure 1 presents a conceptual model of the relationships among teachers' rationales, integration opportunities, implementation constraints, and variations in water sustainability learning practices in primary schools.

Figure 1.
Conceptual model of teachers' pedagogical reasoning for integrating water sustainability into primary science education.



Conclusion

This study confirms that primary school teachers have a strong awareness of the importance of water sustainability and can identify various entry points for integrating it into science learning. However, this integration remains constrained by curriculum pressures, resource constraints, and teachers' pedagogical preparedness, resulting in often situational and individual-driven learning practices. This research contributes to the study of ESD by showing that teachers' reasoning about water sustainability reflects both sustainability-related values and practical considerations related to curriculum and classroom implementation. These findings underscore the need for more explicit curricular-pedagogical frameworks, contextualized teacher professional development, and realistic and adaptive learning models to support more systematic integration of water sustainability in primary schools.

Practical Implications

Based on the findings, several practical implications can be identified. First, primary school teachers can use existing science topics as entry points for integrating water sustainability without adding new curriculum content. Second, schools and curriculum developers should provide simple and flexible learning tools, such as concise lesson plans, observation activities, and locally based thematic projects that can be implemented with limited facilities. Third, teacher professional development should emphasize contextual pedagogical strategies, including local case-based training, microteaching, and the sharing of best practices. Fourth, support from schools and local governments is needed to enable pedagogical flexibility through cross-subject projects and collaboration with local communities, ensuring that water sustainability integration does not rely solely on individual teacher initiatives.

Limitations and Implications for Research

This study has several limitations. The data were collected through an open-ended online questionnaire, which limited in-depth exploration compared to interviews or classroom observations. The findings are also context-specific to Indonesian primary teachers and should be interpreted cautiously in other educational contexts. Future research could connect these findings with ESD competency frameworks and explore classroom implementation through interviews, observations, or intervention studies. Involving other participants, such as students, may also deepen understanding of how water sustainability is practiced in primary education.

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Ethics Statements

This study was conducted in accordance with ethical research standards. Participation was voluntary, and informed consent was obtained from all participants prior to data collection. Respondents were assured of anonymity and confidentiality.

Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

Informed consent was obtained from all participants prior to data collection.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

AI Disclosure Statement

The authors used artificial intelligence to assist with language refinement and improve the clarity and readability of the manuscript. All interpretations, analyses, and conclusions presented in this article are solely those of the authors, who take full responsibility for the content of the manuscript.

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Appendix A.*Examples of the coding and theme development process***Table A1.***Examples of the coding and theme development for teachers' rationales*

Participant excerpt	Initial code	Theme
"I think children should learn about water conservation from an early age so they understand how important water is for life."	Early water awareness	Raising environmental awareness
"If students learn how to save water when they are young, it can become a habit that continues into adulthood."	Eco-conscious generation	Raising environmental awareness
"Children should understand that clean water is important and needs to be protected so it remains available in the future."	Availability of clean water	Alignment with SDGs
"Future generations will also need clean water, so students should learn why it needs to be conserved."	Water sustainability	Alignment with SDGs
"Besides learning about water, students can also learn to appreciate and be grateful for the water they have."	Good and being grateful	Character and values education
"Students should be encouraged not to waste water and to use it only when they really need it."	Use water wisely	Character and values education
"I think this topic can help children develop good habits that they can practice every day."	Build positive character	Character and values education
"Children should learn that protecting water resources is everyone's responsibility."	Environmental stewardship	Character and values education
"Students use water every day when they take a bath, so it is easy for them to relate to this topic."	Bathing	Relevance to daily life
"Drinking water is part of students' everyday lives, which makes the topic meaningful for them."	Drinking	Relevance to daily life
"Students use water when washing their hands, clothes, and other things at home."	Washing	Relevance to daily life
"Many students help water plants at home or at school, so they already have experience related to water use."	Watering plants	Relevance to daily life
"Without water, people, animals, and plants would not be able to survive."	Water is a source of life	Supporting science literacy
"Students need to know that water is important for keeping nature and ecosystems balanced."	Importance of ecosystem balance	Supporting science literacy

Table A2.*Examples of the coding and theme development for teachers' perceived opportunities*

Participant excerpt	Initial code	Theme
"When discussing floods and droughts, teachers can also introduce the importance of water conservation."	Natural events	Integration into primary science topics
"Water sustainability can be linked to lessons about a clean and healthy environment."	Clean and healthy environment	Integration into primary science topics
"The topic fits well with lessons about ecosystems and the water cycle."	Ecosystem	Integration into primary science topics
"When learning about natural resources, students can also discuss how water should be used and protected."	Natural resources and environment	Integration into primary science topics
"Water can be discussed as part of maintaining ecosystem balance."	Harmony in the ecosystem	Integration into primary science topics
"Environmental problems affecting the Earth can be connected to water sustainability issues."	Our Earth is in danger	Integration into primary science topics
"Students can discuss their responsibilities in protecting natural resources, including water."	Citizens' responsibility in protecting natural resources	Cross-subject integration through environmental themes
"Students can write stories, poems, or short texts about the importance of saving water."	Write an appeal text, create a poem, or a story	Cross-subject integration through environmental themes
"Daily water use can be used as an example when learning measurement and volume."	Calculating volume	Cross-subject integration through environmental themes
"Students can create posters or drawings that promote water conservation."	Creating artwork illustrating water conservation messages	Cross-subject integration through environmental themes
"Water shortages can help students understand how environmental problems affect people's lives."	Sustainable development and environmental change	Cross-subject integration through environmental themes
"Students can organize simple campaigns to encourage water-saving habits."	Water-saving campaign project	Integration through thematic projects
"Students can record how much water they use at home during the week."	Observation of water use in daily life	Integration through thematic projects
"School clean-up activities can be linked to protecting local water resources."	Environmental cleanliness project	Integration through thematic projects

Table A3.
Examples of the coding and theme development for teachers' perceived barriers

Participant excerpt	Initial code	Theme
"Our school does not have enough facilities to support environmental observation activities."	Lack of supporting facilities at school	Limited resources and facilities
"There are still limited teaching materials and media related to water sustainability."	Limited learning resources	Limited resources and facilities
"Not all teachers are familiar with water sustainability concepts."	Lack of understanding of water sustainability	Limited teacher knowledge and confidence
"It can be challenging to explain water sustainability in language that young children can easily understand."	Difficulty explaining sustainability concepts	Limited teacher knowledge and confidence
"I am not always confident discussing environmental issues beyond the textbook."	Low confidence in teaching sustainability	Limited teacher knowledge and confidence
"There is already a lot of content that needs to be covered in the curriculum."	Dense curriculum focus	Curriculum constraints
"Teachers often prioritize topics that are directly assessed in school examinations."	Competing curriculum priorities	Curriculum constraints
"Students who always have easy access to water often do not see why conservation is important."	Perceived abundance of water	Environmental context
"Students from different environments often have different levels of awareness about water issues."	Local environmental influences	Environmental context
"Children who have never experienced water shortages may find the topic less relevant."	Limited experience with water-related problems	Environmental context
"Project activities usually require more time than regular classroom lessons."	Limited learning time at school	Time limitation
"The available lesson time is often not enough for practical activities."	Insufficient instructional time	Time limitation
"It can be challenging to find teaching methods that are both engaging and suitable for young learners."	Difficulty selecting appropriate methods	Method uses
"Teachers need practical and engaging ways to introduce water sustainability to young learners."	Difficulty packaging explanations	Method uses
"Some learning approaches work well for older students but are difficult to adapt for primary school children."	Challenges in adapting instructional strategies	Method uses

Note. The excerpts presented in this appendix are illustrative examples selected from participants' responses to demonstrate the coding and theme development process. The excerpts were translated from Indonesian into English by the authors. Coding was conducted inductively and iteratively, and themes were refined through repeated comparison and review using NVivo.