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Improving preschool children's understanding of water pollution through experiential learning

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ABSTRACT

Water pollution is a major environmental challenge with important implications for sustainability, public health, and environmental education. This study explored how an experiential learning program was associated with preschool children's understanding of water pollution in a developmentally appropriate way. The study was conducted over a two-week period in a public kindergarten in Greece and involved 18 children aged 4 to 6 years. The intervention was integrated into the regular curriculum and engaged children in observation, experimentation, guided discussion, artistic expression, and interactive learning activities designed to support exploration of the causes, consequences, and prevention of water pollution. Data were collected through individual semi-structured interviews before and after the intervention and were analyzed qualitatively using thematic analysis. The findings showed a clear shift in the children's responses following the program, with post-intervention answers becoming more relevant, coherent, and conceptually organized. The children more often identified water pollution as a human-caused problem, referred to consequences for marine life and people, and suggested practical actions for prevention. These findings suggest that experiential and developmentally appropriate environmental education may support preschool children in forming early understandings of a complex environmental issue and in beginning to express emerging forms of environmental awareness and responsibility.

Keywords: preschool education, water pollution, experiential learning, environmental education, sustainability, early childhood education

INTRODUCTION

Water Pollution as a Global and Everyday Environmental Challenge

Water pollution is widely recognized as one of the most serious environmental challenges of contemporary societies because it threatens ecosystems, human health and the sustainable use of natural resources (Babuji et al., 2023; Du Plessis, 2022; Hai et al., 2018; Vörösmarty et al., 2010). Water is indispensable for life, food production, sanitation and economic activity. Freshwater and marine environments are increasingly exposed to multiple forms of contamination generated by human activity (Bashir et al., 2020; Ejiohuo et al., 2025; Gleick, 1996; Halpern et al., 2008; Jiang et al., 2025). Major sources of freshwater pollution include municipal, industrial and agricultural waste, wastewater discharge, nutrient runoff, power generation and heavy industry (Kato & Kansha, 2024; Mishra et al., 2023; Nishmitha et al., 2025). Water pollution should be understood as a multidimensional environmental issue affecting rivers, lakes, groundwater, seas and coastal ecosystems across diverse geographical contexts (Dudgeon et al., 2006; Lapworth et al., 2012).

Beyond its environmental dimension, water pollution has profound consequences for public health (Lin et al., 2022; Shekhar et al., 2024; Sun et al., 2025). The public health literature has emphasized that microbiologically contaminated drinking water can transmit diseases such as diarrhea, cholera, dysentery, typhoid and polio. Broader water contamination is also associated with chemically polluted and unsafe water exposure (Ashbolt, 2004; Cabral, 2010; Li et al., 2026; Shekhar et al., 2024). Scholarly reviews likewise show that polluted water contributes to infectious disease and to longer term health risks linked to toxic substances and heavy metals (Balazs & Ray, 2014; Bardot et al., 2025; Lin et al., 2022; Zhang et al., 2023). Water pollution should therefore be approached as an environmental problem and also as a social, educational and ethical issue that requires awareness and responsible action from the earliest stages of life (Ardoin & Bowers, 2020; Iwasaki, 2022; Lin et al., 2022).

The Role of Early Childhood Education in Water Literacy and Sustainability

Early childhood education has an important role in sustainability because it shapes how children begin to understand the relationship between human activity and the natural world (Ardoin & Bowers, 2020; Campbell & Speldewinde, 2022; Davis, 2009; Spiteri, 2020). Research commonly frames early childhood as spanning birth through age eight and identifies this phase as a sensitive period for learning and development. Early childhood care and education provide foundations for wellbeing and lifelong learning (Kim & Umayahara, 2010; Knudsen et al., 2006; McCoy et al., 2017). This developmental stage is especially important for introducing early understandings of care, responsibility and respect for natural resources (Ärlemalm-Hagsér, 2013; Dominguez Contreras & Krasny, 2022). In the context of water pollution, early childhood education can help establish foundational water literacy by enabling children to recognize the importance of water for life, notice everyday practices that affect water quality and begin connecting human actions with environmental consequences (Elkin Postila, 2022; Iwasaki, 2022; Kotsis & Gavrilas, 2025; Miller et al., 2014; Senol & Koca, 2022).

This position is supported by research in early childhood environmental education (Davis, 2009). Ardoin and Bowers (2020) in their systematic review of 66 empirical studies, found that most programs involved children aged three to six years in formal educational settings and reported positive outcomes related to environmental literacy, cognitive development and social and emotional development. Their review also showed that effective early childhood environmental education commonly relies on developmentally appropriate experiences rather than abstract instruction alone (Ardoin & Bowers, 2020; Elliott & Young, 2016). This is particularly relevant to the present study because it suggests that preschool classrooms are not too early for environmental themes. They are appropriate settings for introducing foundational ideas about clean and polluted water in ways that are concrete, meaningful and suitable for young learners (Elkin Postila, 2019, 2022; Miller et al., 2014; Senol & Koca, 2022).

A similar conclusion emerges from the literature on education for sustainability in early childhood (Bascopé et al., 2019; Hedefalk et al., 2015; Somerville & Williams, 2015). Hedefalk et al. (2015) observed that research in the field has moved gradually from teaching isolated environmental facts toward approaches that emphasize participation, inquiry and action (Hedefalk et al., 2015). Somerville and Williams (2015) likewise highlighted the growing importance of meaningful engagement with real world sustainability issues in early childhood settings (Somerville & Williams, 2015). This perspective is especially relevant to water pollution because water is part of children's everyday lives through drinking, hygiene, play, weather and encounters with natural environments (Elkin Postila, 2019, 2022; Miller et al., 2014). As a result, learning about water pollution in preschool can connect environmental understanding with familiar daily experiences and can potentially extend beyond the classroom into family routines and conversations (Ballantyne et al., 2001b; Hedefalk et al., 2015; Somerville & Williams, 2015).

At the policy level, UNESCO's curriculum guidance states that sustainability and climate related learning should be integrated from preprimary education onward and should engage learners across cognitive, socio emotional and behavioral domains (UNESCO, 2024). This position reinforces the argument that environmental issues shouldn't be postponed until later schooling. For topics such as water pollution, preschool education can serve as a starting point for developing awareness, care and early environmental responsibility that can later be deepened through more advanced scientific learning. Preschool education should be understood as a foundational stage in sustainability education.

Conceptual and Pedagogical Challenges in Teaching Water Pollution to Preschool Children

Water pollution is an important educational topic and teaching it in preschool is pedagogically demanding. Understanding water pollution requires learners to begin connecting natural systems with human activity, linking everyday behavior with environmental consequences and relating local observations to wider ecological processes (Elkin Postila, 2022; Fridberg et al., 2019; Gunckel et al., 2012). Research on water related learning has shown that these connections are often difficult to construct (Ben-Zvi-Assaraf & Orion, 2010; Covitt et al., 2009; Dickerson et al., 2005). Studies show that learners' ideas about water systems and water resources are frequently fragmented and marked by persistent misconceptions, while understanding water in environmental systems requires reasoning across connected natural and human engineered systems and across multiple scales (Ben-Zvi-Assaraf & Orion, 2010; Dickerson et al., 2005; Gavrilas & Kotsis, 2024). Although these studies were not conducted exclusively with preschool children, they remain relevant because they indicate that water related concepts and systems reasoning are demanding even for older learners (Ben-Zvi-Assaraf & Orion, 2005; Gunckel et al., 2012).

For preschool children these challenges are intensified by the way environmental problems are commonly perceived at this age (Duran, 2021; Erdas-Kartal & Ada, 2022; Gavrilas et al., 2026). Qualitative studies suggest that young children often recognize pollution primarily through concrete and visible signs such as garbage, dirt and harm to animals or plants (Duran, 2021; Tarman & Kent Kukurtcu, 2022). Duran (2021) found that preschool children expressed their perceptions of environmental pollution through drawings and interviews, with their ideas often centered on visible contamination. Tarman and Kent Kukurtcu (2022) similarly reported that preschool children most often described nature pollution in terms of garbage and emphasized that living things would be harmed by it. These findings suggest that young children can identify the visible and moral dimensions of pollution, but they tend to frame environmental problems in more concrete and directly observable terms than in systemic or abstract ones (Papanikolaou et al., 2021).

This creates a significant pedagogical challenge for preschool educators. If water pollution is taught in ways that are disconnected from children's own experiences, developmental level and opportunities for inquiry, preschoolers are less likely to engage deeply with the topic or develop explanatory understanding (Nayfeld et al., 2011;

Peterson & French, 2008; Yıldız Taşdemir & Güler Yıldız, 2024). By contrast when the topic is linked to familiar and observable experiences, such as rubbish in the sea, differences between clean and dirty water, or visible effects of waste on animals, children have more opportunities to participate actively, ask questions and build understanding through direct experience and inquiry (Eti & Sığırtmaç, 2021; Nayfeld et al., 2011; Peterson & French, 2008; Yılmaz et al., 2024). These findings suggest that teaching water pollution in early childhood requires translating a complex environmental issue into concrete, meaningful and developmentally appropriate experiences.

The Importance of Experiential and Play Based Learning in Early Childhood Environmental Education

The pedagogical challenges outlined above make experiential and play based learning especially important in early childhood environmental education. Young children do not typically build robust understanding through decontextualized abstract explanation alone. They learn more effectively when ideas are embedded in inquiry, exploration, interaction and experience (Gavrilas et al., 2025; Gweon & Schulz, 2019; Papanikolaou et al., 2020; Peterson & French, 2008). Rather, early learning is supported through observing, exploring, moving, talking, imagining, experimenting and acting within meaningful contexts (Ardoin & Bowers, 2020; Peterson & French, 2008; Prins et al., 2022). Environmental topics therefore become more accessible when they are connected to direct sensory experience and to situations children can recognize from everyday life (Ardoin & Bowers, 2020; Prins et al., 2022). Research has argued that play-based learning can help young children and teachers develop and connect environmental knowledge through experience. This literature also shows that play and learning need not be treated as opposing processes. Instead, guided, open ended and purposefully framed forms of play can support knowledge building in environmental education (Cutter-Mackenzie & Edwards, 2013; Gontas et al., 2021). Hedefalk et al. (2015) likewise reviewed research on education for sustainable development in early childhood and identified fact based, normative and pluralistic traditions, with the pluralistic tradition placing greater emphasis on children's participation, deliberation and action in relation to sustainability issues. These studies suggest that children are more likely to develop coherent environmental understanding when they are actively involved in constructing meaning through guided experience, participation and inquiry (Cutter-Mackenzie & Edwards, 2013; Hedefalk et al., 2015).

For the topic of water pollution, the value of experiential and play based learning is particularly evident. Although water pollution is conceptually complex, several of its dimensions can be translated into developmentally appropriate learning opportunities for young children through concrete exploration of dirty water, water purification, aquatic life and everyday water related practices (Elkin Postila, 2019, 2022; Feio et al., 2022; Iwasaki, 2022). Children can compare clean and dirty water visually, investigate how water can be purified, represent their ideas through drawings and stories and participate in art or inquiry based activities that connect environmental care with everyday practice (Elkin Postila, 2022; Tümer & Kaya, 2023; Ward, 2013). Through such experiences, relationships between human action, environmental impact and prevention become more understandable to young learners (Feio et al., 2022; Iwasaki, 2022; Ward, 2013).

Research Gap and Research Questions

Although early childhood environmental education and education for sustainability have grown substantially, research has focused mainly on broad themes such as environmental awareness, nature-based learning and general sustainability practices rather than on young children's understanding of specific environmental problems. Earlier work identified major gaps in this field, and later reviews confirm that important conceptual and methodological limitations still remain (Davis, 2009; Ardoin & Bowers, 2020). Preschool children's understanding of water pollution as a distinct issue has received limited attention. This gap matters because water pollution is both environmentally significant and cognitively demanding.

The present study differs from related work in three main ways. First, it focuses specifically on water pollution rather than on environmental awareness or sustainability in general. Second, it uses a qualitative pre- and post-intervention design in order to examine changes in children's verbal explanations, not only their participation in activities. Third, it supplements the interview data with parent observations in order to explore whether children's ideas appeared to extend beyond the classroom context. Accordingly, the study addressed the following research questions:

RQ1. How do preschool children describe and explain water pollution before and after an experiential learning intervention?

RQ2. In what ways do children's responses change in relation to the meaning, causes, consequences and prevention of water pollution following the intervention?

RQ3. To what extent do parent observations suggest that children's classroom learning about water pollution may have extended into home conversations and everyday practices?

METHODOLOGY

Research Design

The present study adopted a qualitative intervention design involving data collection before and after the implementation of an experiential learning program on water pollution. This design was considered appropriate because the study sought to explore whether preschool children would express clearer and more relevant understandings of water pollution following the intervention, while also examining how these understandings were articulated in their own words, an aim well suited to qualitative interviewing with young children (Ponizovsky-Bergelson et al., 2019; Sun et al., 2023). The use of pre-intervention and post-intervention interviews enabled a focused examination of changes in children's ideas about the meaning of water pollution, its causes, its

Table 1. Age-group and gender distribution of the participating children

Age group	Boys	Girls	Total
Pre-kindergarten children (4-5 years old)	5	5	10
Kindergarten children (5-6 years old)	5	3	8
Total	**10**	**8**	**18**

consequences, and possible ways of preventing it, which is consistent with the value of repeat qualitative interviews for tracing change over time (Audulv et al., 2022; Bennett et al., 2020; Makleff et al., 2021). At the same time, because the study did not include a control group, the design does not allow strong causal conclusions, and any observed changes should be interpreted cautiously.

Participants

The participants were 18 preschool children aged 4 to 6 years enrolled in a public kindergarten in Greece. The sample was drawn from a single classroom and constituted a convenience sample, since the intervention was implemented within the natural context of everyday preschool practice. Of the 18 children, 10 were pre-kindergarten children and 8 were kindergarten children. The pre-kindergarten group included 5 boys and 5 girls, while the kindergarten group included 5 boys and 3 girls. The age-group and gender distribution of the participating children is presented in **Table 1**. Parent demographic data were not collected and are therefore not included in the present study. Working with one classroom made it possible to carry out the educational program in a coherent and developmentally appropriate way while maintaining continuity in the children's learning experiences under ordinary pedagogical conditions. Particular attention was given to ethical issues throughout the research process (Flewitt, 2005; Sun et al., 2023). Written informed consent was obtained from all parents or legal guardians before the beginning of the study, and verbal assent was obtained from each child in age-appropriate language (Dockett et al., 2013; Gavrilas & Kotsis, 2025a; O'Farrelly & Tatlow-Golden, 2022). Participation was voluntary, and the children were informed that they could stop taking part at any time if they did not wish to continue (Dockett et al., 2013; Crane & Broome, 2017). All data were handled confidentially and with careful respect for children's rights, dignity, and well-being, in line with established ethical principles for research involving young children (Flewitt, 2005; Sun et al., 2023).

Research Tool

The main research tool was an individual semi-structured interview protocol designed to explore preschool children's understanding of water pollution in a developmentally appropriate manner. Semi-structured interviews were selected because they provide a balance between consistency and flexibility, allowing the researcher to address the same core issues with all participants while also giving children space to express their own thoughts, associations, and explanations in an open and natural way (DeJonckheere & Vaughn, 2019; Ponizovsky-Bergelson et al., 2019). The interview guide included open-ended questions organized around five thematic areas central to the study: (a) the meaning of water pollution, (b) where water can be found in the environment, (c) who pollutes the sea and how pollution occurs, (d) the consequences of water pollution, and (e) possible ways of preventing water pollution. When necessary, simple prompts were used to encourage elaboration and clarification without directing children toward predetermined responses, an approach consistent with child-centered interviewing in early childhood research. This approach was particularly appropriate for preschool children because it enabled them to respond in familiar language and communicate ideas at their own level of conceptual development (DeCosta et al., 2023; Ponizovsky-Bergelson et al., 2019; Sun et al., 2023).

Data Collection Procedure

Data were collected through individual face-to-face interviews conducted at two points in time: once before the educational intervention and once after the completion of the two-week program. Each interview lasted approximately 10 minutes and took place in a quiet and familiar area within the kindergarten in order to support the children's comfort, concentration, and willingness to participate. All interviews were audio recorded with parental permission and were subsequently transcribed verbatim in order to ensure an accurate record of the children's responses. Because the study was conducted in a Greek kindergarten, the interviews were carried out in Greek so that the children could express themselves naturally and without linguistic pressure. For the purposes of reporting the findings in English, relevant excerpts were translated with careful attention to preserving the meaning and nuance of the original responses, consistent with methodological guidance on cross-language qualitative research (Egilsson et al., 2022; Squires, 2009). Since the same interview protocol was used before and after the intervention, the possibility of a test-retest effect was taken into account in the interpretation of the findings.

Data Analysis

The interview data were analyzed qualitatively through thematic analysis, following the framework proposed by Braun and Clarke (2006). Initial analysis began with repeated reading of the transcripts in order to achieve familiarity with the material, after which codes were generated inductively from the children's responses so that patterns and meanings could emerge from the dataset rather than being imposed in advance (Braun & Clarke, 2006). These codes were then grouped into broader thematic categories related to the main dimensions of children's understanding of water pollution. The analytic process was iterative and comparative, with the developing categories reviewed continuously against the full dataset in order to refine their boundaries and ensure that interpretation remained grounded in the children's own language and perspectives (Braun & Clarke, 2006; Nowell et al., 2017).

Particular attention was paid to differences between the pre-intervention and post-intervention interviews so that shifts in vocabulary, conceptual clarity, and the range of children's explanations could be identified systematically. To support the organization and coding of the material, all interview transcripts were imported into NVivo 11. In addition to thematic coding, word frequency queries were used as a supplementary analytic tool to visualize prominent lexical patterns in the children's responses before and after the intervention (Feng & Behar-Horenstein, 2019).

For the purposes of presenting the overall pattern of change across the five interview questions, children's responses were also classified as either acceptable age-appropriate responses or non-acceptable responses. A response was considered acceptable when it included at least one conceptually relevant idea corresponding to the focus of the question, even if the answer was partial, expressed in simple everyday language, or lacked full scientific precision. For example, in response to the question about what water pollution is, answers such as "when people throw rubbish into the sea" or "dirty water because of rubbish" were considered acceptable because they linked pollution to contamination caused by human action. In response to the question about who pollutes the sea, answers were considered acceptable when children identified people, factories, or similar human sources and referred to actions such as throwing rubbish or releasing dirty water. In relation to consequences, responses were considered acceptable when children referred meaningfully to harm to fish, sea animals, or people. In relation to prevention, responses were considered acceptable when children suggested at least one realistic protective action, such as not throwing rubbish into the sea, using bins, cleaning polluted areas, or preventing dirty water from being discharged.

These classifications were used only to show broad developmental movement in the children's responses and should not be interpreted as evidence of full conceptual or scientific mastery. Given the age of the participants, the aim was not to assess precise scientific knowledge, but to examine whether the children were able to express a meaningful and developmentally appropriate understanding of water pollution after the intervention.

Several steps were taken to strengthen the trustworthiness of the analysis. First, all interviews were audio recorded and transcribed verbatim in Greek in order to preserve the children's original expressions as accurately as possible. Second, analytic decisions and the development of codes and themes were documented throughout the analytic process in order to enhance transparency and dependability (Nowell et al., 2017). Third, parent observations were used as a supplementary source of insight regarding whether ideas discussed in the classroom also appeared in home conversations, thus providing a limited form of triangulating perspective. However, these observations were not treated as equivalent to direct behavioral evidence. At the same time, some methodological limitations should be acknowledged. Formal inter-coder reliability was not calculated, and the interpretation of brief child responses inevitably involved researcher judgment. For this reason, the findings should be understood as systematically derived and analytically grounded, but also interpretive in nature.

Figure 1. Children engaging in an age appropriate experiment on the three states of water (Source: Field study)

Educational Intervention

The educational intervention was implemented over a period of two weeks and was designed as an experiential learning program aimed at improving preschool children's understanding of water pollution. The intervention consisted of eight sessions delivered over two weeks, with four sessions per week. Each session lasted approximately 45 minutes, resulting in a total of approximately six contact hours. The intervention was integrated into the regular kindergarten curriculum and developed in a manner appropriate for children aged 4 to 6 years. Rather than relying exclusively on direct instruction, the program emphasized active participation, observation, discussion, experimentation, artistic expression and guided reflection, in line with developmentally appropriate approaches to early childhood environmental education.

The intervention began with introductory activities focused on water as a natural element and on its basic properties. In order to help children become familiar with water before approaching the issue of pollution, an experiment was carried out on the three states of water. Together with the teacher, the children placed water in a freezer in order to observe its transformation into ice, while water was also heated in a small pot until it boiled. Afterwards, the teacher placed the ice, the boiling water and a glass of liquid water on a table so that the children could observe and discuss the different forms that water can take. This initial activity supported the children's understanding of water as a substance that exists in different states and created a foundation for later discussions about water quality and contamination (**Figure 1**).

A second set of activities focused on the observable characteristics of water. Each child was given a glass of water and invited to explore whether water has shape, color, taste, or smell. While making their observations, the children completed simple age appropriate worksheets. These activities encouraged the use of the senses and supported early scientific

Figure 2. Children exploring the observable characteristics of water and engaging with materials to introduce the topic of water pollution (Source: Field study)

Figure 3. Children participating in a simulation of marine pollution to explore the effects of waste and dirty water on aquatic environments (Source: Field study)

thinking through direct observation and comparison. After completing the worksheets, the children also listened to and learned a song about water, which reinforced the topic in an enjoyable and memorable way.

Once this basic familiarity with water had been established, the intervention moved to the central theme of water pollution. The children watched an age appropriate educational video introducing what water pollution is, how it is caused, what problems it creates for people and other living organisms and how it can be prevented or reduced (**Figure 2**). The video provided an accessible introduction to the topic and was followed by a guided discussion in which the children were encouraged to describe what they had seen, express their ideas and ask questions. These discussions supported meaning making, clarified misconceptions and helped children connect the visual information with their own experiences.

A central experiential activity involved the simulation of marine pollution in a large basin filled with water (**Figure 3**). At the beginning of the activity, the basin contained clean water and small toy sea animals, allowing the children to observe a healthy aquatic environment. The children were then gradually invited to add different polluting materials to the water. First, oil was poured into the basin to represent oil spills. Next, various waste materials, such as bottle caps, a plastic bottle and a plastic bag, were added to represent the rubbish that people throw into seas and other water bodies. Finally, water mixed with coffee was poured into the basin to simulate wastewater or dirty discharge. Throughout the activity, the children carefully observed the changes in the water and in the condition of the animals. They compared the appearance of the basin before and after pollution and noticed that the oil and dirt adhered to the toy animals. The children then attempted to clean the basin by removing the visible waste. However they realized that even after these efforts, the water did not return to its original clean state. This activity was particularly important because it allowed children to observe in a direct and concrete way that water pollution alters aquatic environments and that such damage is not always easy to reverse.

The questions that emerged from this activity led naturally to the concept of solubility and to a further investigation of what happens to different materials in water (**Figure 4**). In order to support children's understanding of this idea, an additional experiment was conducted using ten transparent cups filled with water. Different materials were placed in the cups, including coffee, a plastic cap, aluminum foil, sugar, salt, banana peel, flour, oil and paper. The children observed what happened when each material was placed in water and recorded their observations on worksheets. The cups remained in the classroom for two weeks and the children revisited them regularly in order to observe any changes over time. Through this extended observation process, they were able to recognize that some materials dissolve more easily than others, whereas some do not dissolve at all or remain in the water for a very long period. They also observed that the water gradually became dirty and changed in appearance. This longer term activity helped make the ideas of persistence and contamination more understandable by linking them to repeated direct observation.

The intervention also addressed the consequences of water pollution for marine life and human beings. Through the use of images showing sea animals surrounded by waste, the children were encouraged to think about what happens when the sea is polluted and when animals eat rubbish or live in contaminated water. These visual prompts stimulated discussion about harm to fish and other sea creatures and helped the children develop empathy toward living organisms affected by human actions. The children then watched a second educational video focused on the consequences of sea pollution for marine animals and for people. This combination of images, discussion and video enabled the children to connect pollution not only with dirty water, but also with broader ecological and human consequences.

Figure 4. Children observing how different materials behave in water through an experiment on solubility and contamination (Source: Field study)

Figure 5. Children expressing their understanding of clean and polluted seas (Source: Field study)

Artistic expression formed another important component of the intervention (**Figure 5**). After discussing the effects of water pollution, each child was invited to draw two contrasting representations, one showing a clean sea and one showing a polluted sea. This activity offered the children an alternative symbolic means of expressing what they had understood and provided further insight into how they distinguished between healthy and damaged aquatic environments. Artistic representation also supported reflection by allowing children to revisit the topic through image making rather than through verbal explanation alone.

At the end of the teaching unit on water pollution, the children also engaged with an interactive educational game about the sea using the classroom smartboard (**Figure 6**). This final activity functioned as a playful consolidation of learning and allowed the children to revisit key ideas in an enjoyable and participatory way. The use of interactive digital material was especially helpful in sustaining interest and reinforcing concepts that had already been explored through observation, experimentation, discussion and art.

Throughout the intervention, the role of the educators was primarily facilitative. The teacher and the researchers organized learning experiences, posed guiding questions, encouraged observation and reflection and supported children in expressing their ideas without imposing predetermined answers. In this way, the intervention was consistent with an experiential learning approach in which children were active participants in the construction of environmental understanding.

Data Analysis and Results

The data were analyzed using qualitative procedures supported by NVivo 11 software. As part of the analytical process, word frequency queries were used to generate visual word clouds for each interview question before and after the educational intervention. In these visualizations, the size of each word reflected its frequency of occurrence, making it possible to identify which concepts and expressions were most

Figure 6. Children engaging with an interactive smartboard game (Source: Field study)

central in the children's responses at each stage. This procedure provided a useful supplementary representation of the vocabulary children used when speaking about water pollution and helped highlight shifts in language and conceptual focus following the intervention (Feng & Behar-Horenstein, 2019).

The thematic analysis followed Braun and Clarke's (2006) six phase framework, familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and producing the report. The interview transcripts were read repeatedly and coded inductively in order to identify recurring patterns in the children's responses. Analytic decisions were documented carefully in order to strengthen transparency and trustworthiness in the interpretation of the data (Braun & Clarke, 2006; Nowell et al., 2017). Particular attention was given to the ways in which the children defined water pollution, identified where water exists in the environment, attributed responsibility for pollution, explained its consequences and proposed possible solutions. In line with the aims of the study, the comparison between pre intervention and post intervention responses focused not only on changes in vocabulary, but also on shifts in conceptual clarity, causal reasoning and the extent to which children connected environmental problems with human responsibility and preventive action.

All interviews were conducted in Greek in order to ensure that the children could respond comfortably and express their ideas naturally. For the purposes of this paper, the interview excerpts presented below were translated into English with careful attention to preserving the meaning and tone of the children's original expressions, following recommended practices for qualitative research across languages (Squires, 2009).

Question 1: "Do you know what water pollution is? If yes, what is it? If not, what do you imagine it is?"

Before the educational intervention, the children's responses were dominated by uncertainty and fragmented associations. The most characteristic pattern was the repeated use of expressions such as "no" and "I do not know," indicating that the concept of water pollution had not yet been meaningfully formed for most participants. In several cases, the children gave unrelated or highly vague answers, suggesting that they were attempting to infer the meaning of the term without connecting it to an environmental phenomenon. The pre intervention word cloud therefore highlighted words associated with uncertainty and conceptual ambiguity (**Figure 7**).

> **I-2**: "No… I do not know."
>
> **I-10:** "Pollution… I do not really know these things… the sand drinks the water."

Following the intervention, the children's language shifted clearly toward more concrete and environmentally relevant explanations. Terms such as "rubbish," "water," "sea," "dirty," and "throw" became central, showing that the children were now able to connect water pollution with human behavior and the degradation of aquatic environments. Rather than giving

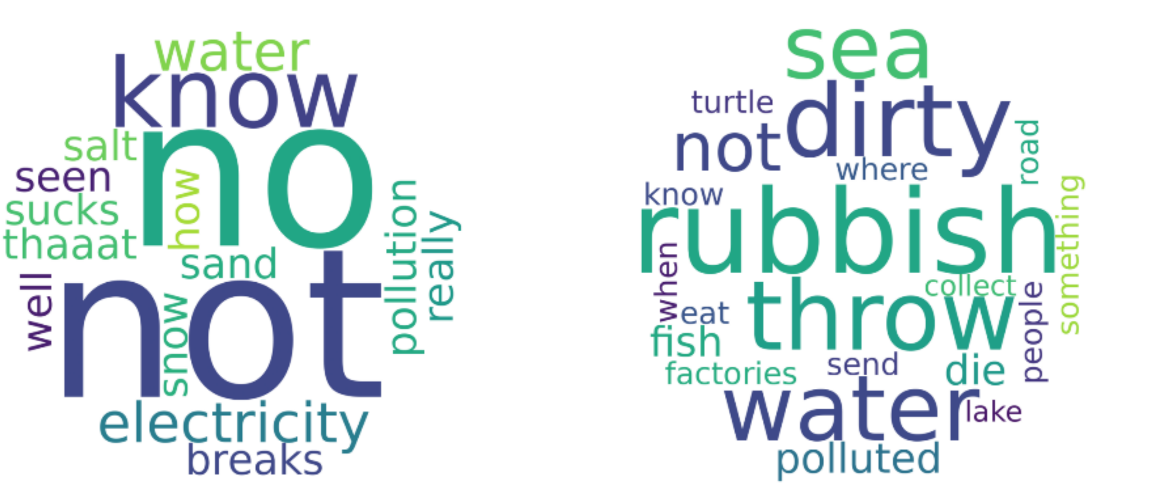


Figure 7. Word clouds of children's responses to Question 1 "Do you know what water pollution is? If yes, what is it? If not, what do you imagine it is?" before (left) and after (right) the intervention (Source: Authors' own elaboration)

Figure 8. Word clouds of children's responses to Question 2 "Where can we find water in the environment?" before (left) and after (right) the intervention (Source: Authors' own elaboration)

vague or unrelated responses, they described polluted water as dirty water caused by rubbish and waste being thrown into the sea or into water more generally. Several children also moved beyond simple definition and referred to the effects of pollution on marine animals. This indicates that the intervention did not simply introduce a new term, but supported the construction of an initial explanatory understanding of the concept. After the intervention, all 18 children gave responses that met the study's broad age-appropriate criteria for an acceptable answer to this question. (**Figure 7**).

> **I-1:** "Yes… when we throw rubbish into the water… it gets polluted."

> **I-9:** "It is when we throw rubbish. The sea can get dirty, a fish or a turtle can eat it, and they can die."

Question 2: "Where can we find water in the environment?"

In contrast to the first question, many children already demonstrated a partial understanding of this topic before the intervention. Their responses commonly referred to familiar and visible places such as the sea, river, lake, rain and tap. This suggests that water as an everyday natural element was already present in the children's lived experience and vocabulary. At the same time, the range of responses before the intervention remained relatively narrow and was mostly limited to the most familiar examples. More specifically, 16 of the 18 children gave acceptable age-appropriate responses in the pre intervention interviews (**Figure 8**).

> **I-1:** "In the well… and in the tap."

> **I-10:** "On the earth… a river… a sea."

After the intervention, the children's responses became richer, broader and more differentiated. In addition to the sea, rivers and lakes, they referred to streams, fountains, wells, waterfalls, dams, canals, beaches, aqueducts and even domestic contexts. This expansion suggests that the intervention strengthened not only recognition of water as an environmental element, but also the children's awareness of the diversity of places in which water exists. In qualitative terms, the change here was less a movement from ignorance to knowledge and more a broadening and organization of already emerging understandings. By the end of the intervention, all 18 children gave acceptable age-appropriate responses to this question (**Figure 8**).

> **I-2:** "In the well, in the lake, in the stream, and at the beach."

> **I-10:** "In the lake, in the wells, in the sea, and in the aqueduct and in the canal."

Question 3: "Do you know who pollutes the seas? Can you tell me how they pollute them?"

Before the intervention, responses to this question were mixed, but uncertainty remained dominant. A few children already associated pollution with throwing rubbish into the sea, yet many others responded with "I do not know" or offered fragmented explanations that did not clearly identify responsibility. Some answers referred vaguely to "ladies and gentlemen," to "salt," or to water itself, showing that the relationship between human action and marine pollution had not yet been clearly understood. Overall, only 3 children provided responses that met the study's age-appropriate criteria before the intervention (**Figure 9**).

> **I-2:** "I do not know… when they throw rubbish."

> **I-18:** "People… no."

After the intervention, the children's answers became much more coherent and causally structured. The dominant pattern was the clear attribution of responsibility to people, often extended to factories and, in some cases, ships. The children repeatedly explained that seas become polluted when people throw rubbish into the water and when factories discharge dirty water. Some responses also included the idea that rubbish sinks to the seabed, remains there for a long time and is eaten by marine animals. This shift shows that the intervention supported a movement from vague recognition of dirt or waste toward a more explicit understanding of human

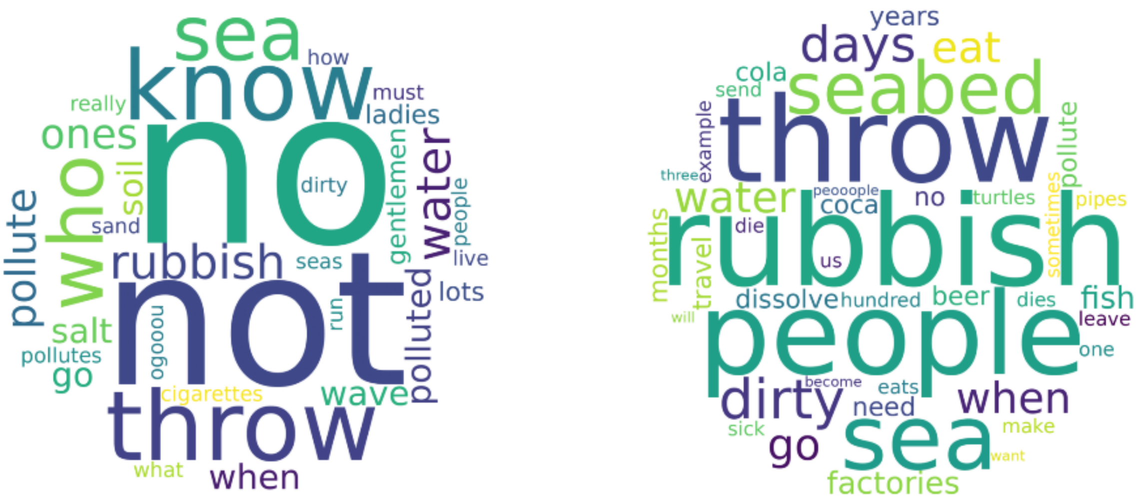


Figure 9. Word clouds of children's responses to Question 3 "Do you know who pollutes the seas? Can you tell me how they pollute them?" before (left) and after (right) the intervention (Source: Authors' own elaboration)

Figure 10. Word clouds of children's responses to Question 4 "What problems are caused by water pollution?" before (left) and after (right) the intervention (Source: Authors' own elaboration)

responsibility and pollution mechanisms. After the intervention, all 18 children gave responses that met the study's broad age-appropriate criteria for an acceptable answer to this question (**Figure 9**).

> **I-1:** "Yes, people… with the rubbish they throw into the sea."

> **I-10:** "People… because they throw rubbish. It takes many years to dissolve, the fish eat it, and then they get sick or die. The factories too… because they leave dirty water."

Question 4: "What problems are caused by water pollution?"

Before the intervention, most children had difficulty articulating the consequences of water pollution. The dominant pattern again consisted of responses such as "I do not know," "no," or brief statements unrelated to environmental impact. Only isolated answers hinted that animals might get sick if objects were thrown into the water. These findings suggest that, before the intervention, the children were largely unable to connect pollution with ecological or human consequences in a systematic way. Only 1 child gave an acceptable age-appropriate response before the intervention (**Figure 10**).

> **I-2:** "I do not know."

> **I-9:** "With the things we throw… if we throw something in, it might go to an animal and it may get sick."

Following the intervention, the children demonstrated a striking increase in conceptual understanding. The post intervention word cloud highlighted terms such as "fish," "animals," "eat," "rubbish," "sick," "die," and "hospital." The children were now able to describe a chain of consequences linking human actions to marine pollution, polluted water to animals eating waste and contaminated fish to possible illness in humans. This is a particularly important finding because it

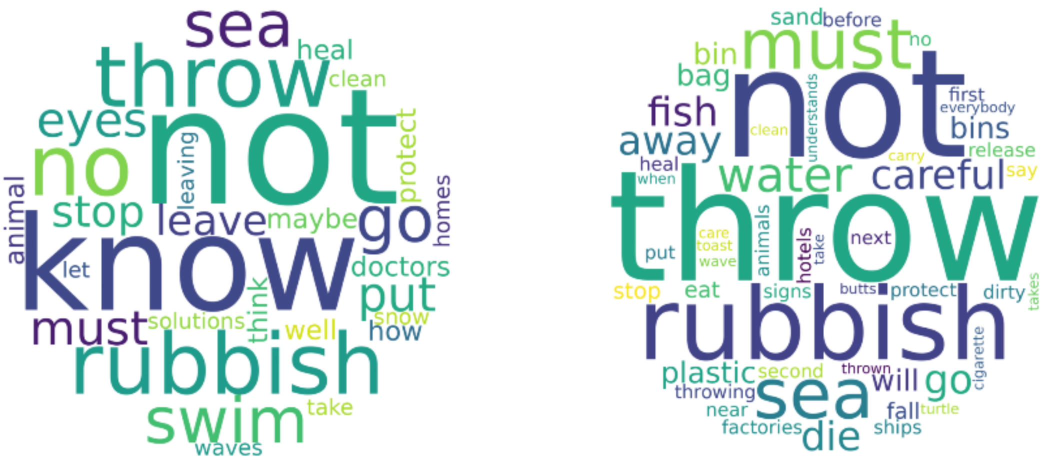


Figure 11. Word clouds of children's responses to Question 5 "What can people do so that this does not happen? Can you tell me some solutions?" before (left) and after (right) the intervention (Source: Authors' own elaboration)

shows an emerging ability to reason through environmental causality across different living beings, rather than focusing only on visible dirt. The post intervention responses also suggest that the children had begun to grasp food related consequences of pollution at an early and developmentally appropriate level. After the intervention, all 18 children gave responses that met the study's broad age-appropriate criteria for an acceptable answer to this question (**Figure 10**).

> **I-1:** "They go to the seabed and the whales or the animals eat them. They get sick... and if a fish is sick from the rubbish and we catch it and fry it and eat it, we can get sick and go to the doctor or the hospital."

> **I-12:** "They throw them into the sea, then the fish eat them, then someone may eat the fish, cook it, eat it, and get sick. The animals get sick and they also die because they eat dirty rubbish and think it is food."

Question 5: "What can people do so that this does not happen? Can you tell me some solutions?"

Before the intervention, the children again showed considerable uncertainty. Although a few were able to suggest that people should not throw rubbish, many answers were vague, impractical, or unrelated to prevention. Some children proposed avoiding swimming, leaving the sea, or having doctors heal the animals. These responses indicate that before the intervention, the children had not yet developed a stable understanding of prevention and environmental responsibility, even when they had some partial sense that something harmful was happening. Only 4 children gave acceptable age-appropriate responses before the intervention (**Figure 11**).

> **I-3:** "No... I do not know."

> **I-9:** "Maybe... doctors... to know how to swim well and go down into the sea and heal the animal."

After the intervention, the children's responses became clearer, more practical and strongly action oriented. The most frequent idea was that people should not throw rubbish into the sea and should instead place it in bins. Several children also suggested cleaning the sea, protecting it, placing signs near beaches and stopping factories or ships from releasing dirty water. This change indicates that the intervention supported not only conceptual understanding of pollution, but also the development of an early sense of environmental responsibility and prevention. The children's post intervention responses show an emerging capacity to think in terms of human action, rules and collective care for aquatic ecosystems. Following the intervention, all 18 children gave acceptable age-appropriate responses (**Figure 11**).

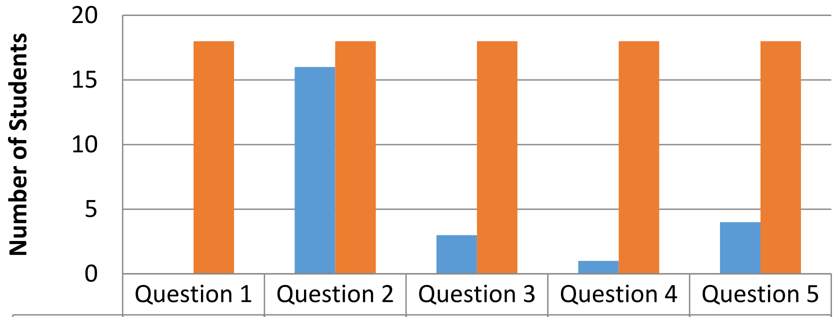
> **I-8:** "First, we must protect the sea so that we do not throw rubbish. Second, the factories and the ships must not release dirty water."

> **I-10:** "We can put some signs that say 'No rubbish' near the sea, next to the hotels, so that everyone understands not to throw rubbish."

Overall Pattern of Change Across the Five Questions

The qualitative findings were further supported by the distribution of acceptable age-appropriate responses before and after the educational intervention, as illustrated in **Figure 12**. A particularly strong change was observed in relation to children's understanding of the basic concept of water pollution. In response to Question 1, none of the children provided an acceptable age-appropriate response before the intervention, whereas after the intervention all 18 children gave responses that met the study's broad age-appropriate criteria. This finding indicates that the concept of water pollution was largely unfamiliar to the children at the outset, but became clearly understandable following their participation in the experiential learning activities.

A different pattern emerged for Question 2, which focused on where water can be found in the environment. In this case, the majority of children were already able to provide acceptable age-appropriate responses before the intervention, showing that water as a natural element was not entirely unfamiliar to them. More specifically, 16 of the 18 children gave acceptable age-appropriate responses in the pre



	Question 1	Question 2	Question 3	Question 4	Question 5
Before	0	16	3	1	4
After	18	18	18	18	18

Figure 12. Number of acceptable age-appropriate responses before and after the intervention across key interview questions (Source: Authors' own elaboration)

intervention interviews. After the intervention, however, all 18 children gave acceptable age-appropriate responses, while their answers also became broader and more differentiated, as shown in the qualitative analysis above.

Substantial improvement was also recorded in relation to children's understanding of who pollutes the sea and how pollution occurs. For Question 3, only 3 children provided responses that met the study's age-appropriate criteria before the intervention. After the intervention, all 18 children gave responses that met the study's broad age-appropriate criteria for an acceptable answer to this question. This shift suggests that the educational program helped children move from vague or uncertain ideas to a clearer recognition of human responsibility and of the specific practices that contribute to marine pollution.

Similarly, in Question 4, which focused on the consequences of water pollution, only 1 child provided an acceptable age-appropriate response before the intervention. In contrast, after the intervention all 18 children were able to identify meaningful consequences, especially in relation to harm caused to marine animals and possible effects on human health. This result is particularly important because it indicates that the children did not simply learn to name pollution, but also developed a clearer understanding of its ecological and social implications.

A comparable improvement was observed in Question 5, which asked children to propose solutions for preventing water pollution. Before the intervention, only 4 children were able to provide acceptable responses. After the intervention, all 18 children gave responses that met the study's broad age-appropriate criteria for an acceptable answer to this question, suggesting that the program also strengthened the children's understanding of prevention, responsibility and environmentally protective action.

Taken together, the results presented in Figure 12 show a clear and consistent pattern of improvement across all five questions. Although some prior knowledge was evident in relation to places where water can be found, the children initially demonstrated limited understanding of what water pollution is, who causes it, what consequences it has and how it can be prevented. Following the intervention, all children gave responses that met the study's broad age-appropriate criteria across the five question areas. This pattern should be interpreted cautiously. It does not indicate complete conceptual mastery and may partly reflect the broad developmental criteria used in coding, repeated exposure to the same interview questions, and the absence of a comparison group. Even so, the findings suggest that the intervention was associated with clearer, more relevant and more organized explanations of water pollution among the participating children.

Parent Observations and Indications of Learning Transfer Beyond the Classroom

In addition to the interview findings, parent observations offered supplementary insight into whether the learning that took place in the classroom extended into the children's everyday lives outside school. As shown in Table 2, all children stated that they intended to act in ways that would protect water and prevent pollution. Their responses most often referred to not throwing rubbish into the sea, disposing of waste in bins, cleaning beaches or water areas and encouraging other people not to pollute. These responses suggest that the intervention did not remain solely at the level of conceptual understanding, but also supported the emergence of early intentions toward environmentally responsible action.

For example, Student 15 stated, "I will not throw rubbish away. I will tell my mother that we should clean the sea so that the little fish do not die." Similar responses were evident across the dataset. Many children referred not only to their own future actions, but also to the role of parents, relatives, or peers, suggesting that they were beginning to understand environmental protection as a shared form of responsibility rather than as an exclusively individual action.

The parent responses largely supported this interpretation. According to the parents' reports, nearly all children discussed at home what should and should not be done in relation to water pollution. Only one parent indicated that the child had not referred at home to issues related to water pollution. Most parents reported that their children talked about not throwing rubbish into the sea because fish and other animals might eat it, become sick, or die. In several cases, parents also described their children reminding family members to behave more responsibly in everyday situations.

Table 2. Water pollution: Students' intended future actions and parents' observations of increased interest

Student	Question to the student: *What will you do from now on so that you do not pollute water?*	Question to the parent: *Did you notice an increase in your child's interest in water pollution? If yes, please provide examples.*
Student 1	Well, I will collect the rubbish and throw it in the bin, because if I throw it outside into the sea, the sea will become polluted.	Yes. He told us what we should not do in the water so that there is no pollution and that we should not waste water without reason.
Student 2	I will not throw rubbish away and I will collect the rubbish.	He learned that when we throw rubbish into the sea, the fish eat it, get sick and die.
Student 3	I would collect it, meaning the rubbish.	Yes. He asked us whether we recycle and keeps pointing it out when he notices that we waste water unnecessarily.
Student 4	Yes, I will collect the rubbish in a little bag that will be safe. I would also tell a child to leave the little animal alone and let it go back into the sea.	Yes. She told me that we should not throw rubbish into the lake so that the water does not become polluted.
Student 5	I will not throw rubbish on the sand. I will throw it in the bin, because if we throw rubbish down, the little animals eat it.	Yes. Every time we go to the lake and she sees branches or rubbish, she tells us that we must collect them and that the little fish will die if we do not.
Student 6	I will not throw rubbish away. We will clean the sea.	Yes. He advises us not to use detergents and cleaning products too often. He does not want to see the tap left open and worries about rubbish being thrown into the sea.
Student 7	I will not throw rubbish into the sea. I would say to a child, "No, do not do that," because the little fish will die.	Yes. He told us that when we go to the sea in the summer, we must be careful not to throw rubbish and pollute it.
Student 8	I will not pollute it. When I go to the sea, I will swim and I will not pollute it. I will tell my mother, "Mum, that is rubbish, let us pick it up."	Yes. She says that we must not throw rubbish into the sea because some animals, such as fish, may swallow it and choke or become polluted. She also says that if people eat these fish, they may become sick as well.
Student 9	No, I will not take things, I will only take water to make sandcastles. I will collect the rubbish.	Yes. He was explaining to his sister how not to pollute the sea because the animals were getting sick.
Student 10	I will throw my rubbish in the bin.	Absolutely. He changed his daily habits in relation to water use, hand washing and so on and he talks about the need to keep the seas clean.
Student 11	I will throw the rubbish in the bin. I will tell my mother and father not to throw rubbish into the sea. I would say to a child, "This is bad. Do not throw rubbish in."	Yes. He explained to us that water coming out of the washing machine can be cleaned and then used for watering plants or washing cars, but not for drinking.
Student 12	I will collect the rubbish. I will not throw rubbish away, especially not my mother and father. I will tell my uncle not to throw cigarette butts, because they are dirty and we can get sick.	He was talking about the rubbish we throw into the water and how it pollutes it.
Student 13	I will collect it and throw it in the bin. I would say no to a child, because it will pollute the sea.	At the beach we should not throw glass or plastic bottles and the same applies to rivers.
Student 14	I will take care of the animals. I will throw the rubbish in the bin.	No.
Student 15	I will not throw rubbish away. I will tell my mother that we should clean the sea so that the little fish do not die.	Yes. He told me that we must not throw rubbish into the sea because the fish die.
Student 16	I will tell my mother and father not to throw rubbish away. I will throw it in the bin, in the blue one and in the green one.	Yes. He emphasized to us that we must not throw rubbish into the sea.
Student 17	I will throw it in the bin and if there is no bin, I will keep it in my hand until we get home.	At beaches we should not throw glass or plastic bottles and the same applies to rivers.
Student 18	I will collect rubbish. I will collect rubbish and throw it in the bin.	Yes. When we went for a walk to the lake, he told us that fish get sick because of rubbish.

Note. Student identifiers are pseudonyms used to preserve anonymity. Student and parent responses were originally given in Greek and translated into English for the purposes of this paper.

The response of the parent of Student 15 is particularly illustrative. The parent reported, "Yes. He told me that we must not throw rubbish into the sea because the fish die." This comment closely reflects the child's own statement and suggests that the environmental message was transferred from the classroom to family conversation. Similar patterns were visible in many of the parent comments, where children were described as explaining the consequences of marine pollution to siblings or adults and as insisting on cleaner behavior during visits to beaches, lakes, or other outdoor settings.

An additional point of interest concerns the fact that several parents also reported changes in the children's everyday attitudes toward water use more broadly. Although the intervention focused primarily on water pollution, a number of parents observed that their children had become more careful not to waste water at home. For instance, the parent of Student 10 stated, "Absolutely. He changed his daily habits in relation to water use, hand washing and so on and he talks about the need to keep the seas clean." This suggests that the intervention may have fostered a broader environmental sensitivity, extending from concern about polluted water to more general awareness of water protection and responsible use.

At the same time, these findings should be interpreted with caution. Parent observations provide indirect evidence and reflect family perceptions rather than independently verified behavioral measures. Nevertheless, they remain valuable because they indicate that the intervention may have influenced children's thinking and everyday expressions beyond the immediate classroom setting. Overall, the parent reports suggest that the children were not only able to articulate ideas about water pollution during the post intervention interviews, but were also beginning to translate these understandings into comments, reminders and actions in daily life. In this sense, the findings point to an encouraging degree of learning transfer from the school context to home and family settings.

DISCUSSION

The findings of the present study suggest that participation in the experiential learning program was associated with clearer and more developmentally appropriate understandings of water pollution among the participating preschool children. Across the post-intervention interviews, children gave more relevant, coherent, and conceptually organized responses about what water pollution is, who causes it, what consequences it may have for animals and humans, and what actions may help prevent it. Interpreted cautiously, this pattern supports a central argument in early childhood environmental education: young children are able to engage meaningfully with environmental issues when these are approached through concrete, participatory, and age-appropriate learning experiences rather than through abstract verbal explanation alone (Ardoin & Bowers, 2020; Hedefalk et al., 2015).

An important feature of the findings is that the observed change was not limited to vocabulary growth. Before the intervention, many responses were uncertain, fragmentary, or based on isolated associations. After the intervention, children more often organized their ideas around simple but meaningful explanatory sequences: people throw rubbish or dirty substances into water, water becomes polluted, animals or humans may be harmed, and people should act to prevent this. This matters because understanding water in environmental systems is widely recognized as cognitively demanding. Water literacy requires learners to connect visible events with less visible processes and to relate natural systems to human activity across different scales (Covitt et al., 2009; Gunckel et al., 2012). At the same time, research with young children suggests that their initial ideas about environmental pollution are usually grounded in concrete and visible elements such as rubbish, dirty water, and harm to living things (Duran, 2021; Tarman & Kent Kukurtcu, 2022). The present findings therefore suggest that preschool children can begin to form early causal understandings of water pollution when the issue is translated into observable, discussable, and experientially accessible forms.

The character of the intervention appears important for interpreting these outcomes. Water pollution was not introduced as a set of scientific facts to be memorized. Instead, children encountered it through a sequence of observation, experimentation, guided discussion, visual material, drawing, and interactive activities. Such an approach is consistent with research showing that early childhood environmental education is most effective when it is rooted in participation, inquiry, and meaningful experience (Ardoin & Bowers, 2020; Cutter-Mackenzie & Edwards, 2013; Hedefalk et al., 2015). It is also consistent with studies in preschool science education suggesting that inquiry-oriented participation can support children's explanatory language and help them build more coherent understandings of phenomena (Peterson & French, 2008). More specifically, Teresa Elkin Postila (2022) found that preschool children could engage seriously with questions of dirty water and water purification through collaborative, hands-on, materially mediated explorations that combined talk with drawing, building, testing, and shared documentation. In this respect, the present study adds support to the view that experiential and play-based pedagogies are not merely motivational tools, but important mediators of conceptual development in early environmental learning.

The study also contributes to the literature by focusing on a specific environmental issue rather than on environmental awareness in broad terms. Reviews of early childhood sustainability and environmental education note that much of the field has concentrated on general themes such as nature connection, environmental awareness, or sustainability practices, whereas fewer studies have examined how young children understand particular environmental problems in their own right (Ardoin & Bowers, 2020; Gavrilas et al., 2024; Hedefalk et al., 2015; Somerville & Williams, 2015). Water-related studies in early childhood do suggest that young children's understandings can be supported from the preschool years onward. For example, Senol and Koca (2022) reported gains in preschool children's water literacy, while Iwasaki (2022) found that environmental education can support young children's water-saving behaviors. Even so, issue-specific work on preschool children's understanding of water pollution remains limited. The present study therefore contributes to the field by suggesting that preschool children can move beyond vague awareness toward more organized and meaningful understandings of a clearly defined environmental issue when learning is carefully scaffolded.

Another important outcome concerns responsibility, care, and the moral framing of environmental problems. After the intervention, children did not only describe polluted water as "dirty"; they also referred more often to what people should or should not do, to protecting fish and sea animals, and to keeping water clean. This pattern suggests that the intervention was associated not only with emerging conceptual understanding, but also with early expressions of environmental responsibility. Such a finding fits research arguing that education for sustainability should not be reduced to the transmission of facts, but should also involve participation, deliberation, and action-oriented meaning making (Hedefalk et al., 2015). It also aligns with work showing that environmental learning in early childhood is often relational and value-laden, linking knowledge with empathy, care, and responsibility toward more-than-human life (Cutter-Mackenzie & Edwards, 2013; Elkin Postila, 2022). In that sense, the findings support the view that preschool children can begin to interpret water pollution not merely as a visible mess, but as a human-caused problem that raises questions of responsibility and prevention.

At the same time, the relationship between children's expressed attitudes and actual behavior requires careful interpretation. The post-intervention interviews and the parent comments suggest that many children were beginning to articulate environmentally responsible intentions, such as not throwing rubbish into the sea, using bins, reminding others not to pollute, or expressing concern for marine animals. These are encouraging findings, but they should not be treated as equivalent to verified or stable behavior change. The attitude–behavior relationship in environmental education is complex, and expressed concern does not automatically translate into consistent action, especially in early childhood where behavior remains closely shaped by family routines, adult guidance, and situational context. For this reason, the present study speaks more strongly to changes in children's understanding, language, and stated intentions than to confirmed long-term behavioral transformation.

The parent observations nevertheless add a useful complementary perspective. Reports that children talked at home about not throwing rubbish into the sea, about animals being harmed, or about the importance of not wasting water suggest that classroom learning may have extended into family conversation. These reports should not be interpreted as proof of behavior change, but they do indicate that the educational experiences may have had communicative and relational reach beyond the classroom. This is broadly consistent with research on intergenerational influence, which suggests that environmental education can stimulate discussion between children and family members and may sometimes contribute to environmentally relevant practices in everyday life (Ballantyne et al., 2001a; Ballantyne et al., 2001b; Gontas et al., 2020; Straub & Leahy, 2017). In this study, the parent data are best understood as triangulating perspectives that support the possibility of learning transfer, while also remaining indirect and interpretive rather than independently verified.

The findings should also be interpreted in developmentally realistic terms. Although the post-intervention responses were stronger, they remained concrete and closely tied to visible forms of pollution and familiar consequences. This should not be considered a weakness. Rather, it reflects an age-appropriate starting point for understanding a complex environmental issue. Research on water systems has shown that invisible pathways, large-scale systems, and long-term environmental processes are difficult even for older learners to understand fully (Covitt et al., 2009; Gunckel et al., 2012). The educational value of the present study therefore lies not in demonstrating full scientific mastery, but in showing that preschool children can develop accurate early foundations for later learning when complex environmental issues are made tangible, discussable, and pedagogically accessible. In this respect, the study is also consistent with Feio et al. (2022), who found that direct contact with aquatic ecosystems and hands-on investigation improved children's knowledge and awareness of aquatic environmental problems.

A more critical interpretation is also necessary in relation to the research design. Because the study used a qualitative pre- and post-intervention design without a control group, the observed improvements cannot be attributed confidently to the intervention alone. It is possible that part of the change reflected maturation, increasing familiarity with the interview format, repeated exposure to the same questions, or other classroom experiences occurring during the same period. This issue is especially important given the very strong post-intervention pattern reported across all five question areas. These outcomes are better interpreted as showing that children's post-intervention responses met broad age-appropriate criteria for acceptable understanding, rather than as indicating full conceptual mastery. The findings are therefore consistent with the educational value of the intervention, but they do not demonstrate causal proof in a strict sense. This point is important not only methodologically, but also interpretively, because it prevents overstatement of what can reasonably be concluded from the data.

The study also has practical implications. It suggests that water pollution and related sustainability topics need not be postponed until later schooling. In preschool settings, such issues can be introduced through carefully designed sequences of observation, inquiry, experimentation, representation, and discussion that connect scientific ideas with children's everyday experiences. At the same time, the findings suggest that this work should be approached with developmental sensitivity. The goal is not to expect abstract scientific understanding at a very early age, but to support the emergence of foundational concepts, causal connections, care for living things, and beginning forms of environmental responsibility. In that sense, the present study supports a curricular approach in which environmental education is treated as an integral part of early learning while also recognizing the developmental limits and methodological cautions that accompany research of this kind.

CONCLUSIONS

The present study explored how preschool children described and explained water pollution before and after participation in an experiential learning program. Following the two-week intervention, the children's responses became clearer, more relevant, and more conceptually organized across all five question areas. In particular, the post-intervention interviews suggested stronger age-appropriate understanding of what water pollution is, who contributes to it, what consequences it may have for animals and humans, and what actions may help prevent it.

These findings should be interpreted cautiously, yet they suggest that developmentally appropriate experiential learning may support preschool children in forming early understandings of a complex environmental issue. Rather than indicating full scientific mastery, the results point to emerging conceptual foundations that may be important for later environmental learning. In this respect, the study supports the view that environmental topics, including water-related problems, can be meaningfully introduced in preschool when they are approached through concrete, participatory, and experience-based activities.

The study also contributes to the literature in two main ways. First, it adds to the growing field of early childhood environmental education by focusing on water pollution as a distinct environmental issue rather than addressing environmental awareness only in broad terms. Second, it highlights the value of examining children's own verbal explanations in order to better understand how young learners make sense of environmental problems. In this way, the study suggests that preschool education can serve as an important starting point for the development of early environmental understanding, care, and responsibility.

At the same time, the findings do not demonstrate stable behavior change or causal proof of intervention effectiveness. Instead, they more modestly indicate that the participating children were able to express more meaningful and developmentally appropriate understandings of water pollution after the educational program. The parent observations further suggest that these ideas may have extended into family conversations and everyday contexts, although such evidence remains indirect and should be interpreted with caution (Ballantyne et al., 2001a; Straub & Leahy, 2017).

LIMITATIONS

Several limitations should be acknowledged. First, the study involved only 18 children from one public kindergarten in Greece. The findings should therefore be understood as context-specific and cannot be generalized broadly to other educational settings or populations.

Second, the study employed a qualitative pre- and post-intervention design without a control group. As a result, the observed changes cannot be attributed confidently to the intervention alone. Other factors, such as maturation, repeated exposure to the same interview questions, growing familiarity with the interview process, or additional classroom influences, may also have contributed to the post-intervention pattern.

Third, the classification of responses as acceptable was based on broad age-appropriate criteria rather than on strict scientific accuracy. This was appropriate given the developmental level of the participants, but it also means that the findings should not be interpreted as evidence of complete conceptual mastery. The strong post-intervention pattern is therefore better understood as indicating meaningful early understanding rather than full or stable knowledge acquisition.

Fourth, the analysis relied primarily on qualitative interpretation of relatively brief child responses. Although the analytic process was documented carefully and supported by verbatim transcription, thematic analysis, and supplementary parent observations, researcher judgment remained involved in the interpretation of children's answers (Nowell et al., 2017; Sun et al., 2023). In addition, formal inter-coder reliability was not calculated, which should be considered a methodological limitation in relation to qualitative rigor.

Fifth, the parent reports provided useful complementary insight, but they represent family perceptions rather than independently verified behavioral evidence. For this reason, they should be treated as indirect indicators of possible learning transfer rather than as proof of actual behavioral change. Finally, because the interviews were conducted in Greek and reported in English, some nuance may have been reduced in translation despite careful efforts to preserve the children's intended meaning (Squires, 2009).

FUTURE RESEARCH

Future research could build on the present study in several ways. Studies with larger and more diverse samples, including children from multiple classrooms or schools, would help examine whether similar patterns emerge across different educational contexts. Research designs that include comparison groups would also strengthen interpretation by making it easier to distinguish the effects of the intervention from maturation, test-retest influences, or other classroom-related factors.

It would also be valuable for future studies to include follow-up data collection in order to examine whether children's understandings are sustained over time. Longitudinal work could help clarify whether early conceptual gains remain stable and whether they later support more advanced environmental learning. In addition, combining interviews with classroom observations, child-produced artifacts, or behavior-oriented measures could provide a richer picture of how children's expressed ideas relate to actual practices and emerging environmental responsibility.

Finally, further issue-specific research is needed in early childhood environmental education. While broad themes such as sustainability and nature connection remain important, studies focusing on particular environmental issues, such as water pollution, water conservation, waste, biodiversity loss, or climate-related phenomena, may offer more precise insight into how young children understand environmental problems and how educators can support that understanding most effectively (Ardoin & Bowers, 2020; Hedefalk et al., 2015; Somerville & Williams, 2015).

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AI statement: The authors stated that AI based tools were used solely for language editing and stylistic refinement. All aspects of literature selection, conceptual development, analysis, interpretation and the final conclusions remain the full responsibility of the authors.

Declaration of interest: The authors declare that they have no competing interests.

Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to corresponding author.

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