

Water education: A valuable tool for water sustainability

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ABSTRACT

Introduction: Water is a fundamental natural resource for health, social well-being and sustainable development. Despite the implementation of technical and institutional measures, water challenges persist, highlighting the need for interventions that also focus on human behavior. In this context, education is recognized as a critical factor in shaping sustainability-oriented approaches to water management. The aim of this study is to review and synthesize the literature on water education, with emphasis on educational levels, thematic units, pedagogical approaches and reported learning outcomes.

Methods: A narrative literature review was conducted in international scientific databases. Studies were selected that concerned educational initiatives and interventions on water within the context of Environmental Education and Education for Sustainable Development.

Results: The findings show that most interventions are implemented in primary and secondary education and utilize experiential and participatory pedagogical approaches. Most studies document positive effects on knowledge and attitudes, while data on long-term behavioral change remain limited.

Conclusion: Water education contributes substantially to strengthening water culture and environmental awareness, while highlighting the need for more systematic evaluation and further research on long-term educational outcomes.

Keywords: Environmental education, Education for Sustainable Development, water education, water literacy, water sustainability.

Introduction

The environmental problems facing humanity are numerous, critical, interrelated and directly linked to human activities and pressures on ecosystems. These specific actions create problems such as climate instability, depletion of natural resources, energy insecurity and air pollution,¹ which require immediate international action. Water is a natural resource vital for the survival of living organisms and ecosystems. It is also essential for social and economic development,² as many activities are inextricably linked to it. Nevertheless, only a

limited share of the Earth's water resources is readily accessible and exploitable, with pollution posing an additional threat.³ Approximately 2.5 billion people remain without access to basic sanitation services, while over 1 billion face inadequate access to safe drinking water. At the same time, water scarcity is increasing worldwide, with developing countries being hit hardest.⁴

The growing world population, the rapid development of industry and agriculture, and the improvement of the quality of life are factors that

lead to an ever-increasing demand for water, at a time when its supply is decreasing due to pollution and unsustainable groundwater extraction.¹ According to United Nations estimates,⁵ global water use has increased at a rate approximately twice that of population growth over the last century, leading to situations in which water availability is insufficient to meet demand. In 2021, it was estimated that approximately 800 million people lived in areas experiencing high or extreme levels of water stress.⁶ In addition, nearly 4 billion people face periods of severe water scarcity lasting at least a month each year, according to data that takes into account seasonal changes in water supply and use. Nearly half of this population lives in China and India.⁵

Water scarcity is expected to increase, particularly in sub-Saharan Africa, unless water production increases significantly in the coming decades. Annual water withdrawals are projected to be 20-50% higher in 2050 compared to 2020, based on current trends.⁶ Even if global warming is limited to 1.3-2.4 °C by 2050, an additional 1 billion people will experience severe water scarcity. Extreme climate events (heat waves, severe and frequent droughts, etc.) are projected to further exacerbate water scarcity in many nations and regions.⁷ Economic scarcity is another important factor contributing to water insecurity, in addition to natural shortages. Many populations lack access to adequate water due to economic constraints that make it difficult to access available water resources.⁴ Of the natural hazards that threaten the global community, water-related hazards account for close to 90%.⁸

The lack of safe and adequate water in many regions of the world, together with inefficient water management, has contributed to the global water crisis, which has led, among other consequences, to high mortality rates.⁹ According to the first United Nations World Water Development Report, the global water crisis stands out as the challenge with the greatest impact on human survival and the long-term sustainability of the planet.¹⁰ Many countries have

tried and are still trying to mitigate the water crisis. However, the legislative or technical measures they have taken have not been able to end or even mitigate this issue,¹¹ leaving billions of people struggling to survive. According to the World Water Assessment Program (WWAP) report, the lack of public recognition of the severity of the water crisis, combined with the lack of appropriate and sufficient skills for a consistent response, creates obstacles to timely interventions.¹²

To address the water crisis, it is imperative that water policy and management are implemented effectively and in a way that allows human activities to develop sustainably.¹³ Given the nature of environmental problems, including the water crisis, is considered deeply social, their management requires a redefinition of the relationship between humans and the environment, in order to achieve their harmonious coexistence. This change requires a lifestyle shift and a reshaping of human behavior regarding water, with an emphasis on establishing an ethical code.¹ Changing these human values and attitudes is possible through promoting awareness of international and complex environmental issues, for which social, economic and ecological goals must be combined and reconciled.¹⁴

In promoting social awareness focused on water conservation and sustainable management, education plays a fundamental role. This orientation of education is linked to a comprehensive and far-reaching change in society and in the approach to the human-environment relationship, which also requires a fundamental change in our perceptions of the role attributed to individuals.¹⁵ Through appropriate knowledge and skills, education can shape individuals with readiness and insight, capable of understanding the complex and multi-layered nature of environmental problems, such as the water crisis, so that they can explore in depth both the value system behind their root causes and the choices made at the individual, social and political levels, as well as be able to formulate strategies and take actions to address them.¹⁶ After all, as Hoy & Stelli

report, people respond more favorably to education and awareness-raising, as opposed to the imposition of legislative restrictions.¹⁵

It is no coincidence that the need for active citizen participation, as a necessary condition for achieving the goals of sustainable planning, has been included in the key points of the latest World Conferences. In this direction, education acts as a catalyst, as it prepares the individual for action by providing not only scientific knowledge, but also a moral dimension.

Throughout its long history, Environmental Education (EE) or Education for Sustainable Development (ESD), as it has come to be known, has gone through various stages of development in response to the escalating environmental issues facing societies around the world. Its evolution reflects our growing understanding of the complex interactions between nature and humanity, with the aim of preserving the environment, a common good, essential for sustainability.¹⁷ The ESD supports the transformation of knowledge into responsible attitude and practice, promoting sustainability as an element of everyday life and social participation. Undoubtedly, when citizens are informed, they can protect and sustainably use water resources, and not only that, but also improve the prevailing situation on the planet.¹⁸

The value of environmental education has been recognized by the International Community at international and regional conferences and meetings and is supported by international and regional organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), the European Union (EU), the Organization for Economic Co-operation and Development (OECD) and the Council of Europe (CE). The urgent need to integrate the key points of environmental sustainability into all levels of education is evident in the 2030 Agenda for Sustainable Development. This recognition has strengthened international efforts to introduce environmental education into curricula at all levels of formal education, as well as in training

programs. It is also promoted by environmental, state and non-state organizations, associations and companies mobilized in the environmental sector.^{1,19,20}

The Nordic countries, and especially Sweden, through a multitude of initiatives, policies, research and actions, are considered pioneers in integrating sustainability into their educational systems. The national curriculum in Sweden includes environmental education, which places a strong emphasis on critical thinking and interdisciplinary learning. Swedish schools prioritize supporting students in understanding complex environmental concepts and encouraging them to actively engage in sustainable behaviors, as part of achieving one of the sixteen national educational goals related to Sustainable Development.²¹ To achieve these goals, sustainable development is taught and promoted in nine-year compulsory education (7-16 years old), either individually in all subjects by teachers or through cross-curricular teaching. This approach has been applied since 1980, usually in secondary education, through thematic units where various teaching approaches of the respective fields coincide.²¹

Environmental Education and Sustainable Development are also highly valued in Denmark. Danish educators, aware of pollution issues and concerned about the availability of water resources in light of ever-increasing pollution, had been trying since the 1960s and 1970s to raise awareness among parents and students about these issues. As a result, environmental education should have a prominent place in high school and, together with other policies and actions, strengthen the sense of responsibility and active participation in caring for the environment.²² These methods used in Nordic countries demonstrate a commitment to developing the skills and mindsets needed for students to actively support sustainable development, in addition to teaching environmental issues.²³

For the most effective implementation of ESD, all stakeholders (policymakers, educators, students,

parents, community) are required to act in synergy to promote environmental sustainability. This implies (Fig. 1):²⁴

- Policy and vision for sustainability and their subsequent integration into educational strategies that shape the education system: clearly defined national guidelines with specific goals and actions in which students play an active role, participation of all stakeholders in strategic planning, positive school culture, training and capacity building among teachers and principals, opportunities for continuous professional development, collaboration platforms, etc.
- Integrating critical environmental issues into the curriculum (e.g. climate change, water crisis, etc.) and promoting key competencies, skills and attitudes such as critical and systemic thinking, a culture of responsibility, collective decision-making, future orientation, etc.
- A learning environment with appropriate infrastructure, innovative practices, teaching

facilities and educational materials are part of sustainability education. Student-centered and action-oriented pedagogical methods that support inquiry and interdisciplinary learning, collaboration, problem-focus, and linking formal and informal learning to develop key sustainability competencies.

It also requires adequate resources (funding, time, materials), adequate educational evaluation tools and monitoring procedures to document the impact of new policies and programs related to ESD, as well as reviewing learning environments that can motivate students to act for environmental sustainability.²⁴

Figure 1 outlines the main policy, curricular, pedagogical and institutional elements that need to work together for the successful integration of ESD into education systems and for supporting learners in developing the skills and attitudes required for sustainability.

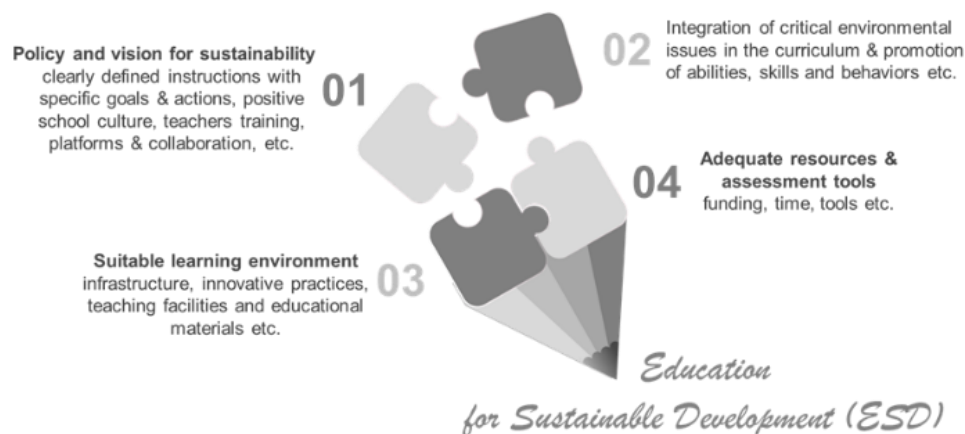


Figure 1: Key factors involved in the effective implementation of Education for Sustainable Development

Strengthening institutional leadership is crucial for wider acceptance of the principles of ESD. However, the implementation of environmental education programs around the world is influenced by cultural, political and educational factors. For example, in the United States, ESD has been widely integrated into school curricula. However, states and school districts may vary significantly in their scope of application.²⁵

Environmental education programs are a global need and can be a powerful tool for building sustainability.²⁶ Of primary importance in the ESD is the development of skills and this should be done after careful selection of the topic, which should include elements of topicality and criticality for mechanisms of sustainable future development.²⁷

Water availability and quality are undoubtedly key challenges. The importance of water as a

fundamental condition of life, the complex global interactions and the potential for action make it a valuable thematic area for the ESD.²⁷ In order to achieve sustainable development, it is essential to combat the pressures on water resources and ensure their security. Progress in their management can be achieved when technical and legislative measures are combined with changes in human behavior,¹⁹ and the adoption of sustainable values, and this can be achieved through education.²⁸ Education can enhance the formation of active citizens who participate responsibly in water management. This active participation is based on understanding the natural environment and human impacts, as well as on developing skills that allow for the recognition of complex interdependencies and the implementation of appropriate management practices.^{29,30}

This literature review captures the role of water education as a mechanism for shaping knowledge, attitudes, and practices that support sustainable water management, and examines the context of relevant educational programs in terms of educational levels, thematic units, pedagogical approaches, and reported learning outcomes.

Methods

Focusing on water education initiatives, this literature review used a structured approach to explore how education could change attitudes as well as behaviors regarding water resources management. This study focuses on examining the development processes of various educational initiatives, the program content and existing case studies.

A comprehensive search was conducted in four major academic databases: Scopus, Springer, Web of Science and ScienceDirect. The search strategy was designed to identify a wide range of studies related to water education within the context of Environmental Education and Education for Sustainable Development. Indicative search terms and combinations included: "Water Education, Water Education for

Sustainability, Water Education Programs, Environmental Education, Education for Sustainable Development", combined with logical operators (AND, OR), to ensure coverage of both the educational and broader framework of sustainable water management.

The search yielded a significant number of relevant publications. After removing duplicate records, the results were subjected to a two-stage screening process. Initially, titles and abstracts were screened to assess relevance to the review topic. Potentially eligible studies were then reviewed in full text to determine whether they met the inclusion criteria.

The review included studies that addressed the organization, content, or evaluation of water education initiatives and interventions, as well as studies that examined the impact of education on knowledge, attitudes, or perceptions regarding water resources management. Empirical and case studies were preferred, while only peer-reviewed academic articles, conference proceedings, and scientific book chapters were considered. The review included recent publications in the English language.

Studies were excluded when they did not focus on water education, did not adequately describe educational interventions, or lacked a clear educational dimension. From the selected studies, data were extracted on the educational context, level of education, thematic units, pedagogical approaches and reported results. The synthesis was carried out through thematic analysis to identify key patterns, best practices and research gaps. The quality of the studies was assessed based on the clarity of methodology, educational design and adequacy of outcomes, and only studies with sufficient data were included.

The interpretation of the findings should consider the methodological constraints associated with this review. Its narrative rather than systematic approach does not allow for quantitative comparisons or estimation of effect sizes, but focuses on identifying key thematic trends. At the same time, the heterogeneity of

studies in terms of educational contexts, target groups and pedagogical approaches limits the comparability and generalizability of results, especially in relation to long-term behavioral change. Finally, there may be language and

publication limitations, as the review is based primarily on peer-reviewed English-language studies. Nevertheless, it offers a coherent picture of the main trends and challenges in water education in the context of sustainability.

Results

The synthesis of the reviewed literature suggests that by supporting individuals and communities in addressing water challenges, future generations can be empowered and bring about change. However, although social awareness of environmental protection and knowledge have increased in recent years, the problems have not been resolved or mitigated.²⁰ This finding shows the gap between knowledge and the adoption of pro-environmental behaviors.

The reviewed literature shows that the transmission of knowledge and skills related to water can be implemented either within the framework of formal education or informally by Non-Profit Organizations or other entities (e.g. museums, water treatment plants, etc). Water education processes are addressed to both children and adults,¹⁹ however the findings show a clear emphasis on formal education, particularly primary and secondary education.

Many countries include water education in their curricula. Table 1 presents indicative examples of countries with different strategies and levels of integration of water education into the curricula.^{3,19,26,31,32,33} These programs are essential tools for educators and include water resource sustainability issues. Different levels of education should be taken into account in the design of programs, so as to leverage existing knowledge, reinforce concepts and skills, and develop new ones.¹⁹ Therefore, there should be continuity in curricula and sustainability education activities in primary and secondary education. It has also been argued that academic programs should allow students to focus on specific sustainability issues and that such

programs should include clearly defined learning objectives along with clear methods for achieving and assessing them.^{24,34}

The prerequisites for the successful implementation of water education programs include adapting them to the cognitive level of students and adopting interdisciplinary approaches,¹⁹ as water education is part of the ESD. In all the studies reviewed, water education programs cover a wide range of thematic areas. The main topics covered in the existing literature are “water as an environment and source of life, water needs and resources, water uses, water treatment, conservation methods, water saving, water quality and the effects of pollution, the water cycle, the spatial and temporal dynamics of water, the geological action of the sea, watershed management, chemical composition and properties of water, water as a source of energy, water as a dynamic element of the landscape, water and climate, water and hygiene.”¹⁹

Examining these thematic areas can lead to the development of fundamental competencies for sustainability (e.g. interdisciplinary knowledge acquisition, critical thinking and proactive action). For example, examining the ecological, economic and health dimensions of water, as well as the ways in which they interact, can enhance interdisciplinary teaching approaches, as these issues are directly linked to students’ consumer behaviors.²⁷ Discussions initially take place on a local scale, but activities are not neglected on a global scale, in order to understand the unequal availability of water.³⁵

Table 1: Information from countries implementing water education programs

Country	National strategy	Education Level	Bibliography
Pennsylvania	• Watershed and Wetland Education • Teacher training and support • Supporting material for participants	Preschool to higher education	Gruver et al., 2009
Singapore	• Water - central role in the education of future generations • Innovative approach to sustainable water management and climate change issues • Exploratory learning • Revision 2006, 2010, 2014	Preschool to higher education	Irvine et al., 2015
Guangzhou, China's 3rd largest city	• Water education has not kept pace with economic growth • Limited reference (0.2–1.4%) to water conservation in 4 compulsory courses • A need for a systematic curriculum is highlighted	Primary Secondary	Xiong et al., 2015
Morocco	• Interdisciplinary approach to develop skills and values • Broad subject matter • Limited presence of field-based and extracurricular activities	Primary Secondary	Amahmid et al., 2018
Spain	• In-depth treatment of the concept of water • Optional courses • Training that requires further strengthening • A need for institutional adjustments is noted	Secondary	Martínez-Borreguero et al., 2020

A successful water education program effectively combines various learning objectives and offers a “*balance between knowledge, attitudes and behaviors*.”¹⁹ Learning processes should support understanding of the different aspects of water-related issues (environmental, economic, social and cultural),³⁶ as students combine them with sustainability.³ Curricula should be developed in a way that connects different aspects of sustainable development. They should also use innovative pedagogical methodologies to encourage students to act on challenges by finding solutions¹⁹ for the sustainability of this precious natural resource. Experiential, participatory and learner-centered methods are often mentioned in the literature.

Experiential pedagogical methods that promote a better understanding of aspects of sustainability, such as water management, are cornerstones.¹¹ Water-themed activities can be organized that incorporate practical real-life situations and are based on environmental concern.³⁷ These activities may include problem-based learning, case studies, poster design, workshops, practical assignments and experiments, inter-school competitions, conferences and debates, theatre and the arts, and even interactive learning technologies and digital tools.¹⁹ For example, involving students as water conservation supervisors in their schools or homes allows them to monitor water use, identify potential waste points, and develop strategies to enhance water efficiency. This role

not only enhances problem-solving and leadership skills, but also fosters a sense of responsibility and accountability towards local water resources. One such project is “The BLUTUBE - Chi porta l' acqua a casa? (Who brings the water home?)”, which adapted game activities for primary school students in Lucca, Italy, and showed that games can promote sustainable water use among students and parents.³⁸

In other studies, the use of spreadsheets (Excel),³⁹ smart teaching systems,⁴⁰ the application of virtual reality,⁴¹ have been shown to enhance the curriculum, making water sustainability education more effective, as it increases student participation and motivation.⁴² Additionally, experiential projects such as creating school gardens, orchards, or similar agricultural initiatives provide a practical learning environment where students can apply the principles of water efficiency in agriculture. By participating in activities such as these, students learn practical aspects of irrigation techniques, soil moisture management, and the challenges associated with water scarcity.⁴³ Such experiences have the ability to bridge the gap between classroom theory and real-world applications, thereby deepening students' understanding of sustainable practices. As students observe the direct impacts of their

actions, are more likely to develop a long-term commitment to environmental sustainability, which can inspire further community involvement and support for water-saving policies.⁴⁴

An example of an experiential method is the study by Valenzuela-Morales et al.,²⁶ which aimed to determine the effectiveness of an educational intervention on the knowledge and perceptions of 5th-grade elementary school students (10 years old) in Mexico regarding water conservation. Specifically, students from Ahuacacatlán and San Miguel Laderas (rural areas within the Nenetzingo River watershed with different water availability challenges) were selected for the study and students from the first area were trained for 630 minutes (7 sessions of 90 minutes each) with activities related to a broader water-related topic. Table 2 summarizes the structure and content of the educational intervention, presenting the thematic units, the intended learning dimensions and the pedagogical strategies applied in each session. The results of the educational intervention showed an increase in knowledge and improvement in attitudes and perceptions regarding water use, which were maintained after a period of 3 months compared to the control group (San Miguel Laderas students), who reported similar levels of knowledge.²⁶

Table 2: Overview of the water education intervention sessions conducted in elementary schools within the Nenetzingo River Catchment, Mexico²⁶

Session 1
Students explore the presence of water on Earth, the water cycle, and its primary physical and chemical characteristics through videos, diagrams, and guided explanations.
Session 2
This session focuses on understanding water availability and the concept of watersheds. Learners engage in storytelling and model-making activities to visualize how water moves and is distributed locally.
Session 3
Students discuss the essential role of water for humans, animals, and plants and experiment with the unique properties of water, such as surface tension and solvent ability.
Session 4
The session examines water use and pollution, wastewater paths, and alternative treatment methods like natural wetlands. Learning takes place through educational games, stories, and songs.

Session 5

Learners explore ways to conserve water, identify different types of water, and discuss the reuse of gray water. The activities include watching videos, analyzing diagrams, and building a small model wetland.

Session 6

This session connects healthy habits and community well-being to responsible water management, encouraging reflection through storytelling and class discussion.

Session 7

The final session introduces rainwater harvesting systems, safe rainwater use, and purification methods at home. Students design posters and infographics to communicate what they have learned.

These approaches lead to greater awareness and a stronger sense of responsibility regarding water management.⁴⁵ Thus, students adopt positive attitudes and behaviors regarding water resources.¹⁹ Experiential, integrated learning experiences are best suited to promoting lifelong learning.⁴⁶ Extracurricular activities can also increase the interest of students or the public, enhance their awareness, appreciation of the natural environment and develop appropriate skills, attitudes and values.⁴⁷ These educational actions are often interdisciplinary and incorporate holistic approaches,²⁹ elements of particular importance for environmental education in general.

In extracurricular activities, actions can be carried out that contribute to the investigation of questions such as the origin of water, the actions that affect this natural resource, and also allow students to develop skills that are necessary to identify solutions to sustainability issues.⁴⁸ Such activities include tours of water treatment plants, rivers, water museums, and interactive exhibitions. With these activities, students will better understand the underlying mechanisms, participate in measurements, and learn about the history of water. In addition, there is an emphasis on participatory educational activities that could include a competitive format, leveraging collaborative learning.¹⁹

On the other hand, participation in field research helps students better understand environmental concepts and strengthens responsibility and positive attitudes towards natural resource management.¹⁹ It also promotes students' observational and perceptual skills,⁴⁹ enhances

motivation and curiosity, and enhances retention of the concepts being taught,⁵⁰ which is why field research is a teaching strategy in the curriculum in many countries.^{19,32} Furthermore, experiences taking place in familiar environments, including homes and schools, are well suited to highlighting the effects of everyday behavior.²⁹ They can promote water literacy and culture, helping students understand water issues in their area, their rights and their responsibilities.⁴³

Studies show that educational interventions related to water sustainability have also been implemented in the community context and even include collaboration between volunteers, educators, water professionals and students, highlighting the role of education in supporting local actions in water management. Such a program was implemented between 2017 and 2020 with four community projects of students, researchers, professionals, and the rural community of Manglaralto in Ecuador, which involved the construction of wells for pumping water and other structures (e.g., embankments, green filters), which help in the use and replenishment of aquifers.^{41,51}

Overall, the reviewed literature reports positive outcomes of water education initiatives in terms of knowledge acquisition and attitude change. However, evidence on long-term change remains limited and varies across studies and educational contexts.

Discussion

The findings of this review show that water-related environmental problems are increasingly understood as deeply social. Their effective

management, therefore, requires not only interventions in infrastructure and regulatory measures but also a review of human values and practices. Education emerges as a key mechanism for enhancing ethical awareness, social responsibility and evidence-based decision-making regarding water sustainability.

In this context, education on water-related issues should be a lifelong process and should also include all stakeholders and users. This entails promoting interdisciplinary approaches to provide the necessary knowledge, skills and values to achieve water sustainability.¹⁹ Substantial and lasting change in water management depends on the ability of individuals and communities to understand complexity and act accordingly. These approaches should include all water uses (e.g. urban, agricultural, industrial, energy, domestic) by providing education in schools, vocational and technical education, as well as to policymakers, local communities and the media.¹⁹

The review highlights that water education initiatives are mainly implemented within the formal education context, particularly in primary and secondary education. Attitude change should be a concern of the education system and implemented systematically.^{3,27} Compulsory education (primary and secondary) is a very important level of water education, as these developmental stages are crucial for cultivating critical thinking, while teachers greatly influence children.¹⁹ Between the ages of 6 and 16, children develop the ability to understand other points of view, but they also develop social and analytical skills, which help them discern logical relationships.⁵² These elements lead to the understanding and explanation of interdependencies between various concepts, the critical analysis of water-related behaviors, and the identification of solutions.¹⁹

Equipped with these skills, school-age children who are educated to be environmentally friendly with regard to water gain the motivation to

change their behavior and take action to address the water crisis, both at the local and national levels, while at the same time interacting positively with the social environment, promoting sustainable development.⁴³

The school is an environment in which educational processes can be implemented with the aim of forming active citizens, ready to act responsibly in water management. This space provides unique training opportunities, as it brings together many students and there is usually appropriate educational material to achieve the learning objectives.¹⁹

Teachers, whose role is important in water education, implement curricula with appropriate methodologies to achieve educational objectives. It is not enough to design comprehensive curricula if teachers do not have the capacity to implement them and vice versa. Teachers' capacity can be improved through training courses, workshops, exchange of ideas with other professionals, etc.³ However, the effective integration of ESD in schools, of which water education is a critical element, requires support and targeted funding in curriculum design. This would ensure that sustainability education becomes a systematic process and not simply a matter of teacher choice.^{3,34}

Pedagogical approaches appear to play a crucial role in shaping educational outcomes. These lead to in-depth awareness and an increased sense of responsibility regarding water management.⁴⁵ Thus, students adopt positive attitudes and behaviors regarding water resources.¹⁹ Learning experiences that combine practice and integration effectively promote lifelong learning.⁴⁵ Extracurricular activities can also increase the interest of students or the public, enhance their awareness, appreciation of the natural environment and develop appropriate skills, attitudes and values.⁴⁷ These educational actions are often interdisciplinary and incorporate holistic approaches,²⁹ elements of particular importance for environmental education in general. However, the extent to

which these pedagogical benefits translate into long-term behavioral change remains poorly documented, highlighting the need for more systematic and longitudinal evaluation of educational outcomes.

The thematic scope of the studies examined in the review reflects the multifaceted nature of water sustainability, covering issues such as availability, quality, pollution, conservation, watershed management and climate-related challenges. However, studies show that presenting topics such as the water cycle, watershed systems and climate change in school curricula does not automatically encourage students to adopt proactive behaviors regarding water conservation or resource management.⁵³ For example, only a small number of students understand that runoff from rainfall contributes significantly to river pollution or can infer how land use and diffuse pollution affect the water cycle. These gaps make the development of aquatic literacy one of the central educational challenges today.⁵⁴

To maintain behavior change, repetition and continuous practical experience are essential for those participating in training programs. Most importantly, children need role models (e.g., parents, teachers, others) to share and support their behavior, which will aim to conserve water resources.¹⁹ Capacity building is crucial to ensuring water security. This process is essentially supported by policy makers, water sector experts and technicians, local populations, relevant parties and information professionals are an integral part of it. They are the main actors communicating on water issues, influencing the public and shaping opinions. Therefore, they must develop and disseminate sustainable values and practices.⁵⁵ It is important to spread understanding of water issues, as well as to develop the skills of decision-makers and professionals. Developing platforms to exchange knowledge, information, good practices and facilitate collaborations can be profitable in this direction. Choosing appropriate communication methods with an emphasis on new technologies

and experiential activities is also essential to encourage the participation of community members.⁵⁵

Case studies discussed in the literature further demonstrate the potential of experiential educational interventions to improve knowledge and attitudes toward water conservation in diverse geographical and social contexts. Community-based initiatives show that education can contribute to local water management practices by enhancing collaboration between students, educators, professionals, and community members.^{41,51}

These programs should be tailored to the specific needs of the local community. However, to be successful, it is essential to take into account prior knowledge and adapt the topic and activities to the different age context of the audience. Community education can also be implemented by establishing community learning centers and pursuing valuable partnerships with various stakeholders. Communities should also be able to formally participate in the decision-making process.⁵⁵

In the case of community education, schools can also play an essential role, along with higher education institutions, which can be transformed into real, successful examples of water management. By becoming more involved in the issues facing the community, these institutions will share their expertise with the general public, educators, and other water and media professionals in order to enhance the impact of their work on society.⁵⁵

Despite these positive indications and the contribution of water education to promoting informed, responsible water users, the diversity of educational programs limits the comparability of findings and the generalizability of results. Beyond specific educational settings, the effectiveness of water education is influenced by institutional support, sociocultural contexts, and the continuity of educational efforts at different levels and sectors.

These observations also highlight the need for further research that systematically examines the long-term impacts of water education in diverse educational and sociocultural contexts.

Conclusion

Overall, the findings of this review allow for a synthetic approach to the role of water education in addressing contemporary water challenges. Water adequacy and quality are emerging as critical and interrelated issues for modern societies, with direct impacts on the environment, public health and sustainable development. The increasing pressure on water resources makes it clear that water management cannot be based solely on technical and institutional measures, but also requires changes in behavior and social practices.

The results show that water education plays an essential role in enhancing knowledge, awareness and attitudes towards water resources. The relevant educational interventions are implemented in formal and informal contexts, utilizing a variety of pedagogical approaches, with the literature recording overall positive results in the acquisition of knowledge and skills.

However, the available evidence on the maintenance of pro-environmental behaviors over time remains limited, which highlights the need to shift the educational emphasis from the transmission of information to the development of critical thinking, ethical reflection and active participation. In this context, experiential,

participatory and interdisciplinary approaches contribute to a more substantial understanding of complex water systems and to the active participation of learners.

The effectiveness of water education is also influenced by factors related to the context of implementation, such as institutional support, coherence between educational levels and the broader socio-cultural environment. The fragmentation of educational interventions and the lack of systematic long-term evaluation limit the ability of education to consistently contribute to shaping sustainable water-related behaviors.

From a research perspective, the findings highlight the need for longitudinal studies that examine the long-term effects of water education on behavior and decision-making. At the same time, the importance of further exploring the role of emerging technologies, innovative pedagogical tools and the adaptation of educational initiatives to different social and cultural contexts is highlighted.

In conclusion, water education should be prioritized within public policy agendas, social strategies, and democratic and participatory governance frameworks. When supported by collective efforts of all stakeholders, it can contribute to the formation of informed, responsible and active citizens who will defend environmental sustainability and contribute to effective and sustainable water management practices.

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