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Research Article

Sustainable Future through Education for Water

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ABSTRACT

Access to drinking water, sanitation, and hygiene is a human right, although half the world's population suffers from water scarcity. This insufficiency is expected to worsen with rising global temperatures and climate change. Including the entire Society in the management of water resources will bring sustainability to human and ecological systems. Including the Society in the management of water resources will bring sustainability to human and environmental systems. Education can achieve this; however, what are the essential topics in Education for Water (E4W)? In what areas of knowledge is it relevant? This research sought to answer these questions through quantitative analysis. We consulted 44 experts (47% females, 90% having postgraduate studies, and 71% working in the public education sector) and found that the most important E4W topics are Water Quality, Natural Availability, and Renewable Water. Additionally, they mentioned Hydric Resources Management and Awareness of Water. Although this topic is interdisciplinary and interinstitutional, most participants stated that E4W should only be addressed in certain areas of knowledge. In contrast, the authors, in agreement with the United Nations, consider that to strengthen the water security of communities, E4W must become a real object of study at all educational levels and areas of knowledge. This way, we will form and develop the technology that Society 5.0 requires.

Keywords: Hydric Security, Awareness of Water, Education for Sustainability, Environmental Education, Skills for the Future, Professional Education, Higher Education, Educational Innovation

INTRODUCTION

Achieving a sustainable future implies water security for all communities, current and future. According to [1] and [2] this means the availability of adequate water, in quantity and quality, for human supply, subsistence uses, ecosystem protection, and production. In addition, there must be the institutional, financial, and infrastructural capacity to access and use these resources sustainably and to manage the interrelationships and externalities between the different uses and sectors coherently. Finally, there must be an acceptable level of risk to the population, the environment, and the economy associated with water resources.

Weak and fragile water governance will achieve the opposite of water security [2]. Therefore, water governance assumes the existence of clear public policies, an adequate legal framework, as well as robust social participation systems [1],[2]. Education is one of the public policies that experts identify as an ally to solve water problems and strengthen the water security of communities.

This research does not intend to position education for water as a subject to be taught in isolation, or as some topic to be included in the environmental education delivered to students. On the contrary, it invites to see water as what it is, an interdisciplinary topic on which every individual could work at all education levels and subjects.

The literature reports that it is essential and urgent that water information in Mexico is disseminated, accessible, and available to all users to favor water security in the basins [1]. Although this action is necessary and important, the ways to achieve it are not defined. [3] state that it is urgent to take strong measures to protect Mother Earth and suggest enhancing the environmental education of teachers to have a direct impact on the water awareness of students. [4] affirms there is a growing awareness of the urgent need to conserve water and that it is important to monitor students' education for water.

[5] work with Social Practice Theory (SPT) to promote students' water conservation practices based on broader factors, identified using grey literature and survey data. TPS decenters individuals from analysis and directs attention instead to the social and collective organization of practices; broad cultural entities that shape individuals' perceptions, interpretations, and actions within the world [6].

Therefore, we seek to answer two questions to deliver an indispensable, relevant, and pertinent E4W in higher education:

RQ1) Which are the most relevant topics to achieve a comprehensive education for water?

RQ2) Which programs should include education for water in their curricula due to its relevance for their professional practice or field of knowledge?

Our objective is to advance water security in communities through education. The originality of this research lies in the fact that using the Delphi Technique, we approached 44 experts to answer a survey on the contents to be covered by E4W. Herein we report the analysis of their answers and highly valuable opinions. In this way, we will contribute to the human technology required by Society 5.0, which must be prepared to limit and cope with water risks to acceptable and manageable levels, although not to eliminate them [2].

METHODS AND METHODOLOGY:

Literature Review

Water security refers to the ability of the population to safeguard sustainable access to adequate quantities of water of acceptable quality to sustain livelihoods, human well-being, and economic development [7]. Water security raises the relationship between water and society with wide and varied scopes, in addition to the challenge for decision-makers, who must promote strategies that meet the growing human demand for water without compromising fragile ecosystems [8].

Although this is a challenge for decision-makers, it is also a challenge for the population; water security is a characteristic of society, which must develop the capacity to meet its drinking water and sanitation requirements and respect the balance of surface and groundwater bodies.

Society needs to take an interest in protecting its means of livelihood, production, and life. To address these social issues and achieve water security, it is essential to consider education as an ally [9]. Furthermore, as a policy instrument, education plays an important role in raising environmental awareness and promoting conservation behaviors to ensure future water security [8].

Another factor to consider in the conservation of water resources is that climate variability is becoming more and more pronounced, affecting sustainability and the hydrological cycle. Climate changes make wet or dry places more and more extreme; people adapt to these new conditions and become resilient to their circumstances, but this alignment is not enough to achieve sustainable solutions [10].

Success Stories that have Linked Water and Education

[11] affirms that there will not be a single solution to water challenges; on the contrary, there will be a diversity of situations, all adapted to territorial specificities and contexts to adjust water policies to each geographical location. Here lies the importance and transcendence of creating local agents of change, with the sole purpose of providing solutions to problems related to water resources in the basin in which they live.

Knowing the geography and topography of water services is indispensable for their conservation [12],[13] so that issues of this nature should be part of the local education of students of this era. For [14], the key strategies that supported the recovery of the estuary in Bilbao, Spain, were based on the centrality of culture.

The Cultivating Good Water (CAB) project of Itaipu Brazil, was awarded in 2015 with the UN-Water award for best practices "Water, source of life" and attributes its success to the strategy of involving the communities; using a methodology that ensures the broad contribution and inclusion of various social actors, all actively participating from the situational diagnosis to the planning, implementation and evaluation of actions.

The activities promoted by the CAB include experiential environmental education, thus transforming this experience into social technology to help local governments and other countries with water shortages [15].

[16], in the design of its program “New water culture” in primary education: Nenetzingo River Basin, proposes to promote knowledge in children in basic education about the importance and care of water so they can adopt positive attitudes and practices, and face water challenges.

[17] analyzed data from the Nutrient Management Survey conducted by the Louisiana Master Farmer Program to examine factors affecting the adoption of water conservation practices. They found significant results for explanatory variables, one of which is the educational level of producers on the likelihood of adopting conservation practices. These authors bring to the table the importance of discussing the implications of the development of educational policies and programs. They state that a higher level of education is expected to increase awareness of conservation, and its impact on natural resources and improve decision-making on the adoption of conservation practices. In their research, the education variable has a positive and significant effect on the adoption of new practices.

One way to face these problems, within the framework of Integrated Water Resources Management (IWRM), is to improve legal, political, institutional, and human capacities; education is the resource to improve the latter. [18] point out that a profound reform of Mexico's water sector must be carried out, which should include, among other things, the training of human capital, as well as the modification of public policies that have not been able to halt or reverse the trend towards less water security.

The Intergovernmental Hydrological Program of the United Nations Educational, Scientific and Cultural Organization (UNESCO) [19] details in its Strategic Plan six focal themes that characterize water security, including education and water culture as a key element. [20] points out that the basin should be seen as a socio-ecosystem where the complexity of multiple dimensions is combined: Society + Government + Educational institutions.

The Itinerant School of Water for Life (ESITAV), led by Mexican Zapotec women concerned about the water needs of their communities, develops social technology [21]. Through this initiative, they train young people from indigenous and marginalized communities in northeastern Mexico, developing skills and knowledge to implement ecotechnologies for rainwater harvesting, water purification, treatment of soapy water, and water recovery for the regeneration of degraded areas. This project, awarded in 2023 by the Commission for Environmental Cooperation (CEC) as one of the innovative projects in water-related solutions for sustainable development, is successful because it involves the community; participating citizens solve a problem in their immediate environment that affects them directly in their daily lives.

ESITAV is a project that inspires and reaffirms the importance of experiential and meaningful learning. A project that allows students to use their education, and the knowledge developed to solve the problems of their immediate environment. ESITAV makes it clear that there must be a community and its problems where ideas and proposals for improvement that students can develop can converge [21].

As part of the 2021-2025 strategic plan of the Commission for Environmental Cooperation (CEC) between Canada, the United States, and Mexico, it is considered a priority to encourage citizen participation to carry out concrete actions in favor of the environment. Therefore, any teaching strategy should focus on the possibility that students become agents of local change and generate ideas, with a scientific basis and a community action plan, to solve water problems in their watershed. This is the generation of the social technology that the community requires to safeguard water resources in the Anthropocene.

Case Presentation

The approach with experts was through data collection instruments with the conventional Delphi technique based on [22],[23], shown in Figure 1, as a classic forum for the prioritization of factors (Delphi Technique). This technique aims to check the consensus of opinions among a group of experts [other]. For this reason, the aim was to approach the consensus of experts, to prioritize topics to determine the most relevant hydro-social contexts that could have an impact on education. These topics, endorsed by the experts, can be the raw material for designing academic material in all areas of knowledge.

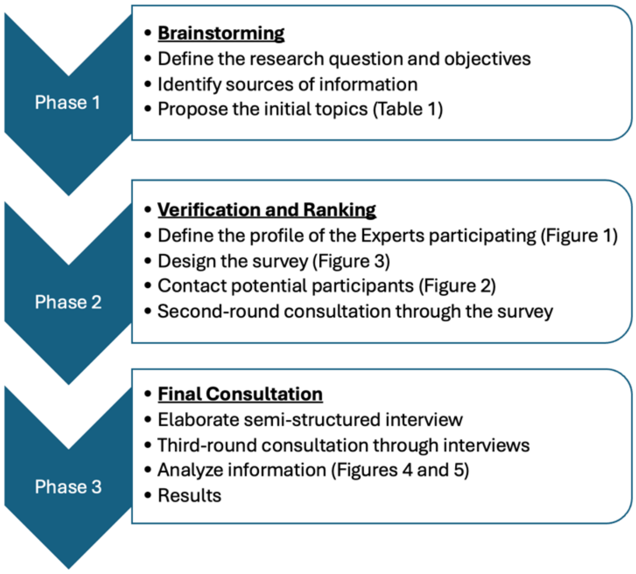

Fig 1. Delphi Technique as applied in current research

Aligning ourselves with the Delphi Technique, for the first phase of the design, the 16 most important topics that appear in the annual report of the Ministry of the Environment and Natural Resources in Mexico [24] were taken, and ratified with those presented by the National Water Information System [25] and the National Water Commission [26] both in the Water Atlas [27] as well as in the Water Statistics [28], and in consensus with the authors, an additional one was added. The topics to prioritize are shown in Table 1, where through the comparison of the different agencies, the first consensus on relevant topics is reached.

As a second phase of the technique, a survey-type instrument was designed, which consisted of 28 questions. The first seven questions had a demographic nature and were closed-ended. The next 17 Likert-scale questions had the purpose to rank each of the topics identified previously in phase one. Finally, the survey had 3 open-ended questions with the purpose of offering the Experts a space to expand and express their opinions. The survey was applied in Spanish and answered online through a Google Forms link. It was disseminated as a direct invitation to each of the Experts.

For this research, Experts should be understood as researchers holding a degree related to water and/or having expertise working on these issues, with teaching commitment. We sent 49 invitations through email under these constraints and 44 responses were received and validated.

As a third phase of the Delphi Technique, we conducted semi-structured interviews to 20% of the experts. According to [23], in this phase there should not be less than 7 participants, so we decided to interview 9 of the experts among those who had answered the survey previously. We selected these experts by convenience, according to their availability. The interview revolved around three questions:

1. How relevant do you consider education as an ally in the solution to water issues?
2. In any of your research works, have you concluded, at least once, that education and/or water culture is the solution to the problem?
3. What would be the appropriate educative approach to promote water culture in undergraduate students?

Current work only reports the analysis of Question 1, while Questions 2 and 3 will be analyzed in the future.

The analysis began with descriptive statistics of the surveyed population and their responses to the instrument. The databases of the open-ended questions were cleaned for analysis with the free application of Voyant tools [29]. The transcripts of the interviews were analyzed with traditional qualitative peer review techniques to answer the research questions through the voice of the experts.

Table 1. Relevant topics for the study of water in water education.

SEMARNAT	SINA	CONAGUA Water atlas	CONAGUA Water statistics	Authors
Water balance	Droughts and Hydrological information		Hydrological cycle	
Precipitation	Precipitation			
Surface runoff	• Aquifers • Piezometric wells			Ground water
Renewable water	Renewable water			
Surface water bodies	Main rivers	Water conservation		
Natural availability		Amount of water		
Water stored in dams	Water dam monitoring			
Consumptive uses of water		Water Uses	Water Uses	
Water in agriculture	Hydrological regions			
Public supply	Drinking water coverage		Impact of water on well-being	
Water Use in Industry				
Virtual water	Virtual water			
Concessioned water	Water use analysis			
Degree of pressure on water resources.			Hydraulic infrastructure	
Water quality	Water quality	Water quality		
Wastewater discharge	Wastewater treatment plant			
	Watersheds			
	Clean and certified beaches			

RESULTS AND DISCUSSION

Figure 2 outlines the years of experience and academic degrees of the Experts who participated in this research. Experts from Mexico and Ecuador participated in this research. 51% of them were Mexican men and 42.9% were Mexican women. The highest percentage of participants have 1 to 5 years of experience with a master's degree, while the most experienced Experts hold the highest academic degrees, accounting for 65.9% of the total sample.

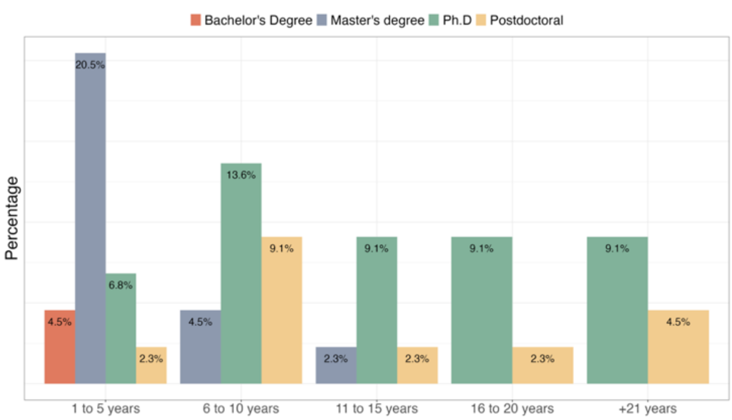

Fig 2. The Experts participating in current research, according to their years of experience and academic degrees

The instrument asked the experts questions 8 to 24, on a Likert scale, from 0 (irrelevant) to 5 (most relevant and necessary), for each of the 17 topics revealed by phase 1 of the Delphi technique. Figure 3 shows the results.

It is worth noticing that for the Experts, the most relevant topics to be included in a E4W curriculum were also those evident for the naive common citizen: Water Quality and Natural Availability, which are topics highly visible to an individual, even more drastically if living inside urban regions. They directly interact with tap water and may notice changes in taste, color or odor; while they may also be aware of water shortages or abundance related to seasons. In contrast, Water Use in Industry and Water Rights are often invisible unless there is a debate or a crisis that brings these issues to public attention. Even more Virtual Water, or the embedded water in goods and services, is not commonly understood nor does it draw awareness.

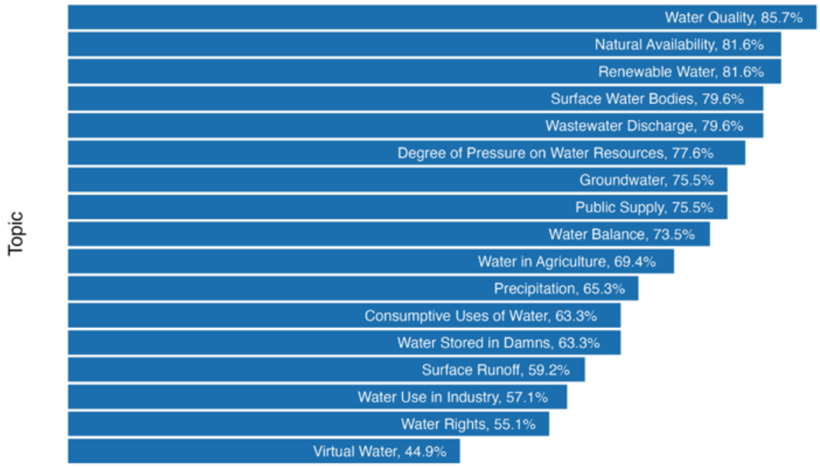

Fig 3. Ranking of the most relevant topics to be included in a Education-for-Water curriculum according to 44 Experts in Water issues from Mexico and Ecuador

Regarding the open-ended question "Is there any topic that you consider transcendent and necessary to be taught in the academic training of students at the middle and high school level to strengthen the culture of water care, and that has not been mentioned in the previous list? Please write it down", 23 of the 44 experts proposed new or different topics to those mentioned. 12 (27%) proposed Water Culture as indispensable to be delivered in Education for Water, followed by 8 (18%) who mentioned Water Resources Management, and finally 3 (7%) mentioned that Wastewater should be present in this Education.

For the question "Which university programs should include the above-mentioned topics in their curricula?", a word cloud was created by means of text analysis. The 25 most frequently mentioned terms in the answers are shown in Figure 4. Most of the Experts (32 participants or 72%) answered that Education for Water should be taught in all those programs related to environmental, science and engineering.

A minority of Experts (16 participants or 36%) recognized that all higher programs should include Education for Water in their curricula. This result shows that, although the literature mentions that water is an interdisciplinary and transverse topic, this is not recognized by the Experts in water issues. Most of them consider engineering to be the program that should address water issues as well as programs related to environmental issues.

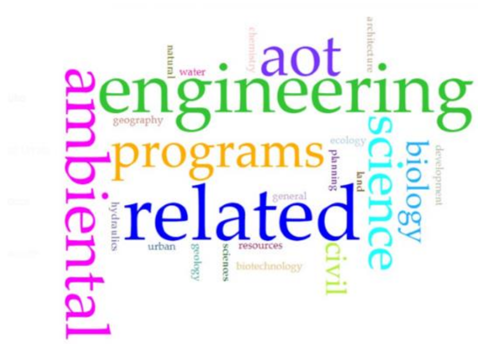

Fig 4. Word cloud showing the 25 most frequently mentioned in response to the question "Which university careers should include the above-mentioned topics in their curricula?"

Figure 5 shows the graph that measures the strength of the relationship between the terms. The terms "environmental" and "engineering" are strongly interrelated. This means that most of the answers constructed their response in phrases such as: "related to environmental engineering". Chemistry and Biology are the subjects they consider important for teaching water-related topics.

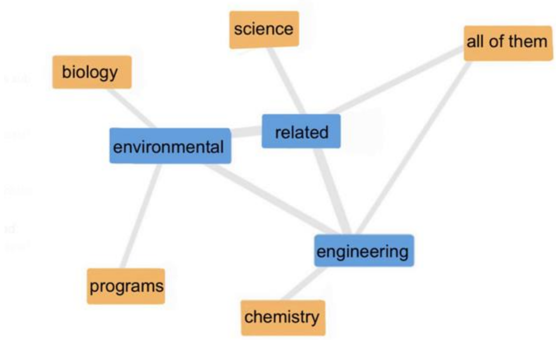

Fig 5. The strength of relation (edges thickness) among the most frequently mentioned terms in the Experts' responses to "Which university programs should include the mentioned topics in their curricula?"

It is also valuable to identify that even though almost 20% of the Experts identified Water Resources Management as a topic to be addressed by higher education students, none of the participants mentioned that programs related to politics, business, administration and social sciences in general should include Education for Water. Under such conditions, we will be seeking for technologies to solve water scarcity, pollution and any other water issue from the technical point of view, without stablishing public policies and strategies that ensure their proper implementation.

The results of the semi-structured interviews (Phase 3 of the Delphi Technique), evidence that 90% (8 out of 9 Experts) clearly identify E4W as a relevant topic for the education of undergraduates. There are three outstanding comments that illustrate how E4W should proceed.

Expert A commented on the importance of recognizing the background of the resources; because it is true that nobody values what they do not know. This Expert invites to teach the students the present and past of the water resources condition, to understand the severity of the current crises but, above all, to make decisions and prevent crisis from worsening in the future. Expert A stated:

"The history of water sows affection and interest in [water] care. Every citizen should know the answers to the following questions: How many springs do remain? How many springs have dried up? How much does water cost you? and why does water cost? Maybe you are living now where there used to be a water board".

Expert B highlighted the importance of knowing the past of water resources to take actions in the present and be able to lessen as much as possible the impacts of the water crisis, which, as the experts say, we must be prepared to limit and manage risks at acceptable and manageable levels, despite the impossibility to eliminate them. Expert B affirmed:

"It is extremely important to know the hydrological cycle, to know where the water comes from, as well as the impact of your actions on the quality and supply of water."

Finally, we must be aware of the limitations of Education, which might not give immediate results but in medium and long terms. This is backed by Expert C who encourages us to engage in immediate solutions through action. This Expert states that reforestation is necessary to recover aquifers and recognizes that education will be of great help, but in the long term. However, at this moment we are living the consequences of the lack of education for water in the past. In words of Expert C:

"Awareness should be sought through empathy. Education for water will bear fruit in the medium and long term. For the short term, actions should be directed or related to reforestation, care and recovery of spaces for aquifer recharge. Education, perhaps as a public policy measure, would be a potential area".

LIMITATIONS AND FUTURE WORK

Herein, we have evidenced the relevance of integrating Education for Water in the curriculum of higher education. We have provided evidence for this affirmation; however, it is important to acknowledge certain limitations when considering its interpretation and generalization. The Delphi Technique was implemented with 44 expert researchers, most of whom come from science, technology, mathematics, and engineering (STEM) backgrounds. Thus, it would be beneficial to include experts from other disciplines, with no teaching commitment and with jobs within the industry. Additionally, this research was not conducted to ensure gender equity or participation from other nationalities different from Mexico and Ecuador. These considerations could improve future work.

CONCLUSION

This research sought to answer two questions to implement indispensable, relevant, and pertinent Education for Water (E4W) in undergraduate programs: RQ1) Which are the most relevant topics to achieve a comprehensive education for water? RQ2) Which programs should include education for water in their curricula due to its relevance for their professional practice or field of knowledge?

Through the Delphi Technique, we approached 44 experts for answers to these research questions. The main findings were:

a) The Experts identified as relevant topics for an E4W curricula those also perceived at a glance by non-experts, such as Water Quality, Surface Water Bodies, and Natural Availability.

b) Concerning additional topics outside the original proposal, Experts mentioned Water Culture and Water Resources Management. In contrast, the analysis concerning the academic programs that should include E4W, Experts did not mention fields like social sciences, humanities, arts, business, or health. They only focused on programs related to environment, natural sciences, and engineering. This might demand further analysis since social sciences include public policies, education, and management, which are critical to effectively implement public policies towards water sustainability.

c) While 90% of the participants identify that E4W is relevant, they recognize that education will not give immediate results, but rather in the medium and long term. It is noteworthy that some experts recommended an educational approach from the history of water resources in the communities, and even, from empathy.

As stated by [18], up to date, education has made isolated efforts to advance water security. Our proposal is clear: Education for Water should be delivered vertically (at all educational levels), interdisciplinary and transversally (from all fields of knowledge) to advance water security. In fact, indicators of the social and economic progress of a society must include E4W. Only in this way, together as a community, we will overcome the complexity of the ongoing water crisis and ensure a better and more sustainable future for all.

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