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"The world is dry, but I am fine" Self-perception of the human right to water and sanitation in trainee teachers

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The water in Mexico does not meet the standards outlined by the United Nations General Assembly in the document "Human Right to Drinking Water and Sanitation" (HRWS). This pertains to potability, acceptability, sufficiency, accessibility, and affordability. An analysis was conducted on the public drinking water service and its impact on the socio-ecological well-being of students attending teacher training schools in Yucatán, Mexico. Online workshops were held using a competency-based methodology. Questionnaires were developed to gather information on the state of public drinking water and sewage services ($n = 200$) to evaluate participants' experiences with public water management. Participants completed a questionnaire assessing their understanding and perception of the HRWS ($n = 200$) and a self-assessment questionnaire ($n = 200$). Findings indicate that 84% acknowledged governance issues in access to water and its quality (questionnaires), while only 11% of students rated their HRWS as poor to very poor (self-assessment). This cognitive dissonance arises from the gap between knowledge about the water service and self-perception. It suggests that the system's inadequacies have become normalized, affecting individuals' willingness to engage in pro-environmental actions and behaviors. The students recognize a water crisis and believe that polluting practices must be addressed. They also feel that increasing public involvement in water management through awareness is essential. However, they do not see themselves as affected by the crisis or as agents of change through their future roles as teachers.

KEYWORDS

perception, environmental education for sustainability, human rights, water, teaching training students

1 Introduction

Water is vital for both human and environmental health; however, human actions have significantly affected its quality and availability (Oki and Kanae, 2006; Jones, 2011; Mishra, 2023). Due to mismanagement, overexploitation, and pollution, 29% of the global population lacks access to safe drinking water (Mehta, 2007; Mehta et al., 2019).

The current water crisis is alarming, with 60% of people worldwide experiencing physical water scarcity, and 61% of households lacking sufficient sanitation (Panhwar et al., 2022; WHO, 2023).

Formal education serves as a crucial instrument to combat poor water management. It raises public awareness and empowers individuals to address environmental and developmental challenges (Kansal and Venkatesh, 2020). Teachers have a key role in this mission, as they can identify, question, and explore the root causes of these issues (Ellerbrock et al., 2016). By analyzing the perceptions and experiences of prospective teachers, we can equip them to influence the next generation's views and strategies on water management (Cankaya and Filik Iscen, 2015; Kowasch, 2023; Yli-Panula et al., 2023). Compared to other aspects, such as thematic knowledge or teaching practices, these issues are among the least explored in education for sustainability (Adelman, 2018; Barrable, 2019; Ruiz-Garzón et al., 2021). This study investigates how future teachers perceive the Human Right to Drinking Water and Sanitation (HRWS) within their community. This research's findings might greatly enhance environmental education and water management by revealing how the perceptions of future educators shape their teaching methods and actions. We conducted a questionnaire to evaluate community perceptions of HRWS compliance and a self-assessment survey to investigate these factors in participants' lives. By comparing the results from both tools, we aim to understand if their perceptions influence their ability to integrate the complexities of water management into their teaching and improve their capacity for action. To our knowledge, no research has been published on this subject in the context of environmental education related to HRWS in Mexico. This topic holds significant relevance given the country's ecological water-related challenges, particularly if existing water management practices continue (Cockerill, 2010; Emmerich and Molineri, 2019).

1.1 Water, human rights, and education

In 2010, the United Nations General Assembly established crucial standards for water quality and quantity, underscoring their importance in sustainability efforts. The Assembly urged all nations to ensure personal and domestic water supplies meet specific criteria (UNGA, 2010): (i) Water delivery must be adequate, providing a steady flow of 50 to 100 liters daily per individual; (ii) Water must conform to quality benchmarks; (iii) Sanitation facilities must be culturally appropriate, considerate of gender, and mindful of life cycles, demonstrating acceptable organoleptic properties; (iv) Access to water and sanitation services should be convenient, located within or near homes (less than 1,000 meters away and within a 30-min walk); (v) Water costs should remain affordable, capped at no more than 3% of a household's monthly budget income.

Sanitation refers to systems that manage human waste, solid waste, wastewater, and drainage to protect health (UN-WATER, 2022). Effective wastewater disposal requires well-maintained sewer networks and efficient treatment plants to remove pollutants before returning the water to the environment or a reuse system. Poor water quality and inadequate hygiene significantly threaten human health and hinder social and economic progress

(Winkler and Satterthwaite, 2017; Lin et al., 2022). These issues are particularly common in rural and peri-urban areas (Yu et al., 2014; Mishra, 2023), where poverty limits access to basic human rights, negatively affecting the ecosystem (Anglés-Hernández, 2016; Hargrove et al., 2018). Additionally, municipal and industrial wastewater is released into the environment without sufficient treatment (Bayu et al., 2020; García-Searcy et al., 2022; INEGI, 2023).

The National Water Commission (Conagua) manages water resources to ensure security and sustainability in Mexico. Municipalities are responsible for providing drinking water, sewage, and sanitation services, as well as handling urban solid waste (Wilder et al., 2020; García-Searcy et al., 2022; Koul et al., 2022).

The karst aquifer system, primarily composed of carbonate limestone rocks, is the primary source of fresh water in Yucatán and the peninsula (DOGEY, 2019). Unfortunately, the National Water Law does not account for the distinct features of this aquifer (DOF, 2023), resulting in overexploitation and contamination. Many people in Yucatán and throughout Mexico do not have access to public water services that fulfill the standards for the HRWS. Over 70% of households nationwide experience water supply challenges, such as low pressure (Guardiola et al., 2010) and insufficient connections to sewage treatment networks. Mérida, the state capital, has thirty-five key domestic wastewater treatment facilities, yet 105 municipalities in the state lack such necessary infrastructure (CONAGUA, 2021). Consequently, less than 3% of the water extracted is treated for reuse (DOGEY, 2019). Yucatán experiences a higher-than-average rate of acute diarrheal diseases in children under five (Yang et al., 2012; Shamah-Levy et al., 2020), which adversely affects both their physical and cognitive development (Lin et al., 2022; Wolf et al., 2023). This pressing issue highlights the urgency and importance of our efforts in research.

The school setting encourages discussion and analysis (Kansal and Venkatesh, 2020; Pegalajar-Palomino et al., 2021; Li et al., 2022), promoting knowledge exchange, shaping perceptions, and inspiring pro-environmental actions, especially among elementary and middle school learners. In some Latin American nations, students at this age gain their first insights into the natural environment; this may comprise their only formal education regarding these topics throughout their lives (Navarrete-Cazales and Ocaña-Pérez, 2022). Hence, it is crucial for teachers to receive training to effectively address sustainability (Young and Malone, 2023), develop the ability to contextualize information, acknowledge the urgency of environmental challenges, and weave ethical values into the human-nature connection (Cebrián and Junyent, 2015; Cebrián et al., 2020; Barrable, 2019). Such training will empower educators to effectively impart knowledge and foster critical attitudes in students, encouraging active involvement with environmental matters (Ellerbrock et al., 2016).

Educational programs in hydrology and hydrogeology currently face notable information gaps. Students find it challenging to link the water-related knowledge acquired in school to the water management practices in their communities (Lázaro-Salazar, 2020). To promote pro-environmental behaviors, it's essential to identify threats and take proactive measures, evaluating the seriousness of environmental issues and personal risk (Rogers, 1975; Floyd et al., 2000; Milne et al., 2000; Rainear and Christensen, 2017). The most effective pro-environmental actions

emerge when the seriousness of environmental crises is recognized and adaptive strategies are developed to mitigate vulnerability (Brownlee et al., 2013; Falkenmark, 2020; Zobeidi et al., 2022). Achieving this necessitates a thorough analysis of resource management and an understanding of how natural systems operate locally and globally (Pakmehr et al., 2020; Shafei and Maleksaeidi, 2020). An effective legal framework, social influences (Lange and Dewitte, 2019), and environmental values and knowledge development are crucial for encouraging behavioral change (Li et al., 2022). Additionally, the school environment significantly contributes to the cognitive development that underpins these behaviors (Brownlee et al., 2013).

In Latin America, the scarcity of research on how this perception gap impacts teacher training and environmental awareness highlights the urgency for studies addressing the region's socio-environmental challenges (Corrochano Fernández et al., 2021). In this context, we pose the following questions: (i) How do teacher trainees perceive their and their community's access to the HRWS, and what gaps exist in their understanding? (ii) To what extent do these perceptions accurately represent the current conditions of HRWS, and how do they influence their engagement with water-related challenges? (iii) How do these perceptions affect their ability to acquire and convey knowledge that contributes to effective water management and sustainable long-term solutions?

This study evaluates how the study population perceives HRWS and its vulnerabilities pertaining to public water and sanitation services. It also explores how these perceptions influence the recognition of vulnerabilities at both the community and household levels, comparing the students viewpoints with actual conditions. Furthermore, the study pinpoints deficiencies in educational materials to inform the development of interventions, ultimately aiming to improve current educational programs.

2 Materials and methods

2.1 Population and sample

The Bioethics Committee for Research in Human Beings authorized the protocol at the Center for Research and Advanced Studies (COBISH-Cinvestav, document No. 096/2022). In Mexico, educators are trained in "Escuelas Normales" (Normal Schools) that cater to different educational levels, such as elementary, intermediate, and high school. The study was conducted in three schools located in Dzidzantún, Ticul, and Valladolid, all in Yucatán, Mexico. Each of the three localities features a notable rural and indigenous population. While these traits aren't the focus of this study, they play a crucial role in understanding how access to HRWS is perceived and interpreted. These schools are part of the public education system and prepare teachers for elementary and middle school education. As the Secretary of Public Education (SEP, 2021) reported, ninety-one percent of teachers graduating from these programs are set to teach in elementary public schools, which serve 80% of the population between ages seven and fifteen.

The sample was selected through convenience sampling based on accessibility and participants' willingness to participate. The study focused on second-semester students (August-December 2022) enrolled in the geography course, with 211 students

($N = 211$) following the existing curriculum. Geography was selected because it focuses on analyzing the interactions among people, abiotic factors, and society, making it the ideal course for this incorporation intervention. An informational session was conducted with the students to outline the objectives and structure of the educational intervention study (electronic modality). Those who consented to participate received a letter of informed consent, which they signed to fulfill this requirement. The letter detailed how researchers would manage the data confidentially, assuring participants there would be no negative consequences for opting out and that they could withdraw from the study at any time.

2.2 Techniques and instruments

The national educational program and the graduate profile for primary education teachers focus on developing professional competencies (DOF, 2018). To ensure this research and its topics are relevant to this educational framework, we chose the model of professional competencies in education for sustainability (CPES; Cebrián and Junyent, 2015). This model offers a systematic framework, enabling educators to blend cognitive and practical skills to incorporate sustainability principles into their teaching practices.

This model is especially pertinent to the Mexican education system because it supports national competency-based policies and promotes the integration of sustainability topics into the curriculum, making the study more replicable. Previous research (Cebrián and Junyent, 2015; Cebrián et al., 2020; OECD, 2019) has shown its efficacy in developing critical thinking and improving problem-solving skills necessary for tackling sustainability issues in various educational settings contexts.

As part of this approach, a table of concepts on water sustainability (Table 1) was developed. This table emerged from an extensive literature review and was specifically aimed at tackling issues related to HRWS. It helped conceptualize HRWS challenges, guiding the creation of items that recognize, contextualize, and critically evaluate access to public water services. The process was aligned with international guidelines by referencing parameters related to the human right to water and sanitation.

2.2.1 Workshop on "The human right to drinking water and sanitation and its impact on public health and ecosystems"

The study was conducted after the school restrictions imposed in response to the SARS-CoV-2 pandemic. The workshop was designed as a digital educational intervention utilizing various online platforms (Martin et al., 2020; Supplementary Material 1). It aimed to achieve three main goals: (i) assisting students in recognizing elements related to HRWS and its importance for ecosystem health, (ii) identifying vulnerabilities linked to HRWS, and (iii) fostering an understanding among students of the importance of effective water management for ensuring quality, availability, and public health. The workshop consisted of three parts: (a) Identifying key water management challenges at global, national, and regional levels, (b) Understanding HRWS, and (c) Examining the relevance of HRWS at both regional and individual levels.

TABLE 1 Professional competencies related to the teaching of HRWS and water resources.

Competencies	Definition	Competencies adapted to Yucatan's Hydrogeology
Contextualization	Understand the spatial and the temporal dimension of the problem.	Changes in land use over time in the Yucatan State.
Knowledge	Theories, principles and concepts of a particular discipline.	Concepts of hydrogeology, karst, hydrology, water crisis in Mexico/world, water-public health relationship.
Alternative scenarios/visions of the future	Visualize future and alternative scenarios.	Visualize the consequences of current freshwater management and management proposals in accordance to future needs.
Critical thinking	Question, recognize and promote critical reflection to understand established assumptions.	Who are the actors within water management? Encourage reflection on the consequences of the current management.
Decision taking, actions for change	Raise awareness and act, share responsibilities and get involved in collective actions.	Advance citizen education and participation in the discussion and proposal of solutions to conserve and protect water.
Value clarifications	Clarify and advance values and rights toward sustainability.	Advance human rights and obligations related to access to drinking water and water justice.

Modified from [Cebrián and Junyent, 2015](#) and [Cebrián et al., 2020](#).

The workshops took place in an e-learning format during extracurricular hours to prevent disruption to students' regular studies. A single instructor, experienced in teaching with specialized training in psychology and human ecology, led all the sessions. The instructor guided the students during the workshop, offered extra explanations when necessary, and facilitated group discussions. Students joined via the Google Meet® platform on Chrome OS (Chrome OSM96, 2022) for 3 h at scheduled times. The sessions included audiovisual materials^{1,2} and involved instructor-led group discussions to examine instances of water injustice, access issues, and sanitation data, while also reflecting on participants' experiences with public water and sanitation services.

2.2.2 Evaluation instruments

The researchers developed digital resources and assessment tools grounded in up-to-date scientific knowledge to fulfill the study's objectives and tackle major issues. A crucial aspect of our study involved validating the evaluation instruments through a rigorous process. This process featured a pilot test conducted in

June 2021 at the Normal School of Ticul, involving 80 former students. The pilot test outcomes verified the instruments' validity and reliability, with analyses revealing a Cronbach's Alpha of 0.60 for the multiple-choice sections and consistent results in open-ended responses. Some items were refined for clarity before the final use, enhancing our data's reliability.

Following the workshop, a survey was carried out to evaluate the community's views on HRWS, collecting insights regarding threats, the seriousness of impacts, and participant susceptibility ([Supplementary Material 2](#)). This survey featured nine open-ended questions divided into three parts: (i) Identifying issues related to water management, (ii) acknowledging potential solutions for management shortcomings and the water crisis, (iii) assessing the effects of the water crisis and the shortcomings in implementing HRWS at home.

After completing the questionnaire, participants used a self-assessment tool ([Supplementary Material 3](#)) to gauge their water security, perceived threats, and risks in daily life. This self-assessment comprised 28 questions organized into three sections: (i) measuring the access, quality, and availability of water at home (via a Likert scale); (ii) evaluating domestic and municipal sanitation in their homes (using yes/no responses); and (iii) providing open-ended responses to questions about (a) how water vulnerability affects public health, (b) the factors that ensure water security, (c) the role of citizens in water management, and (d) current forms of collaboration.

2.3 Data analysis

Data from the evaluation tools, including the questionnaire and self-assessment, were organized and categorized in Microsoft Excel®. An analysis of the responses was performed to identify key categories, patterns, and frequencies, which clarified the concepts the students interacted with. For open-ended questions, participants could submit several responses.

The responses were counted to assess the frequency, and percentages were calculated to show the status of HRWS, governance in water management, and participants' views on water distribution and sanitation issues. The Likert scale responses were analyzed through Cronbach's alpha to measure the internal reliability of the questionnaire. Levene's test was used to evaluate the homogeneity of the variances of the groups being compared. To enhance result visualization and assess adherence to HRWS parameters ([Figure 1](#)), student responses were categorized into: good when students reported that they always received the service, regular for those who indicated they received it almost always or regularly, and bad for those who said they received it rarely or never.

3 Results

Between September and November 2022, six online workshops took place. Two hundred students, accounting for 95% of the second-semester student population from the participating centers, attended these workshops. The

1 <https://youtu.be/z888ADZWl0Y?si=LwyWLpxUDGk1ds39>

2 <https://youtu.be/R51eJoiCY0?si=So4lqmKNxYtMkRo->

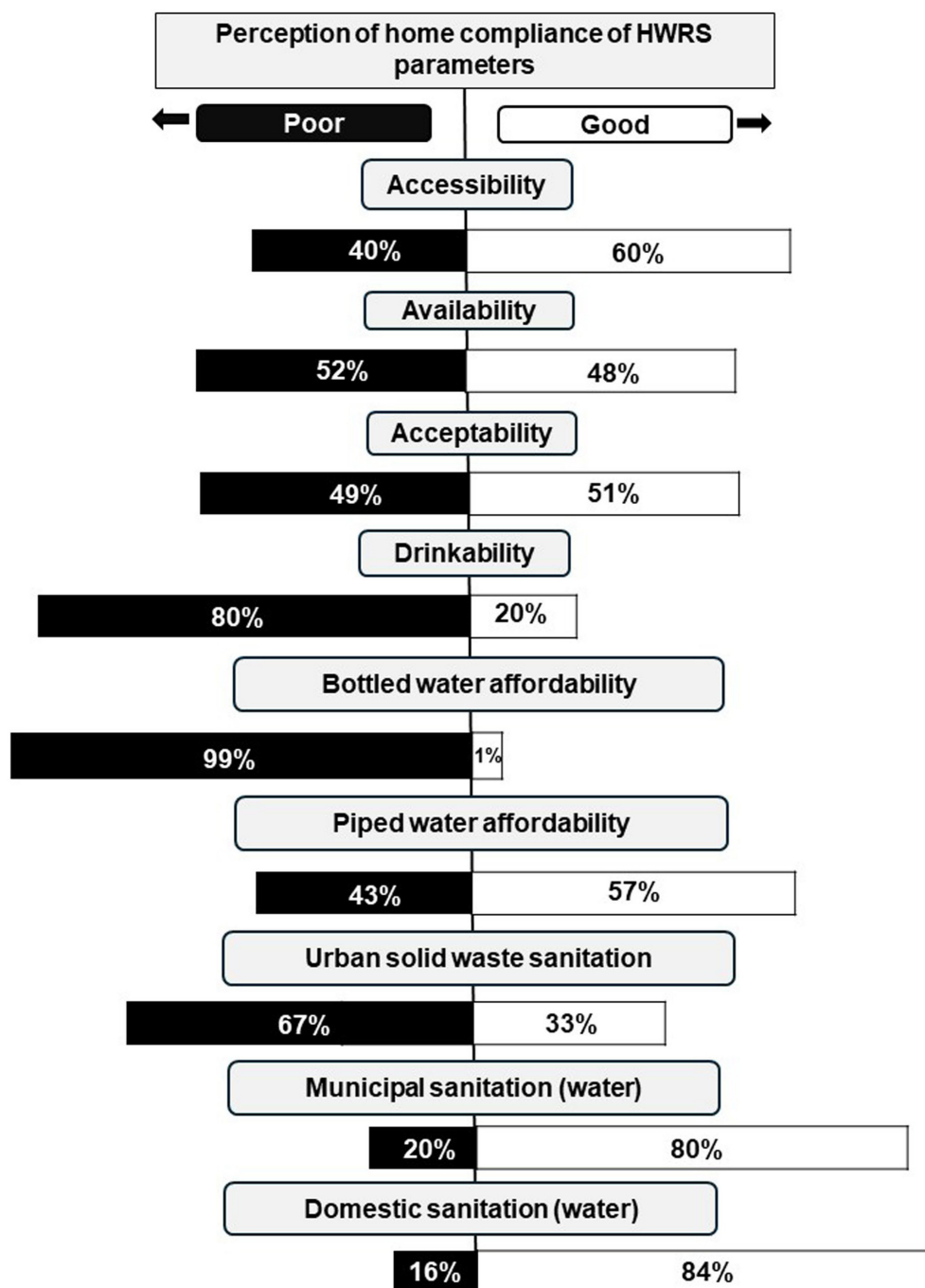


FIGURE 1 Participants perception of the degree of compliance of human right to drinking water and sanitation (HRWS) within their homes.

participants had an average age of 19 years, with 71% being female (Supplementary Material 5).

A total of 400 evaluation instruments were gathered, including 200 questionnaires and 200 self-assessments. The multiple-choice portion of the questionnaire obtained a Cronbach’s alpha of 0.60, signifying acceptable validity and reliability for the instruments in an educational setting (What Works Clearinghouse, 2022). An analysis of the responses from the open-ended sections revealed consistent patterns across all questionnaires, showcasing the construct validity.

After reviewing the results, we combined the three groups of students from the three schools into one sample due to the lack of significant differences. For instance, in Table 2 (Supplementary Material 4), a Levine statistical analysis was conducted on the Likert scale items from the self-assessment, yielding *p*-values exceeding 0.05. This information is particularly intriguing as it indicates that, even though the towns are in different state regions, the public water management approaches are comparable across the three areas where the participating schools are based.

TABLE 2 Questionnaire results on perception of community compliance with the HRWS. Answer frequencies and percentages.

	Perceptions on compliance HRWS community	Frequency of responses	Percentages %
Opinions on hydric crisis and HRWS (<i>n</i> = 200)	Global hydric crisis	170	85
	There is solution to hydric crisis	180	90
	HRWS Vulnerability	146	73
	Importance of HRWS for human wellbeing	69	35
	Failures in the fulfillment of HRWS	58	29
	Importance of citizen participation	18	9
	Failures in legislation	15	8
	HRWS are enforced in the community	8	4
	Lack of interest by citizens	7	3
Inequality between citizenship and corporations	5	2	
Identified problems (<i>n</i> = 205)	Failures in the distribution of water	110	54
	Lack of potability	28	14
	Deficient water domestic infrastructure	26	13
	Lack of sanitation	17	8
	Agro-industrial impact	11	5
	Insufficient collection fees	9	4
	Floods	4	2
Proposed solutions to HRWS problems (<i>n</i> = 275)	Water infrastructure renovation at municipal level	90	33
	Training and monitoring to State employees	67	25
	Awareness campaigns	27	10
	Increase in citizen participation	26	9
	Functional domestic water plumbing	24	8
	Renovation of domestic plumbing	17	6
	Equal water prices all over the state	10	4
	Water culture education	8	3
	Agro-industrial water infrastructure renovation	6	2
Solutions to hydric crisis (<i>n</i> = 263)	Prevention and mitigation of pollution	67	26
	Citizen awareness	65	24
	Increase participation of citizens in water administration	54	21
	Radical changes in water management	32	12
	Radical changes in agro-industrial water uses	23	9
	Changes in education related to water	19	7
	There is no solution	3	1

3.1 Questionnaire results on perception of community compliance with HRWS

Eighty-five percent of the participants acknowledged a global water crisis. They highlighted issues such as drought and water supply challenges in other regions but failed to see the connection to their local circumstances. The remaining fifteen percent rejected the notion of a water crisis. They defended their stance by stating that water frequently reached their homes, that it was plentiful in Yucatan, and that the situation was not as dire as in other

countries. This indicates a lack of awareness about the national water situation. When asked whether the water crisis had a solution, 90% of the students responded positively. The remaining 10% denied that a solution existed and justified their viewpoint by citing the scale of the crisis and the challenges of enacting change due to insufficient knowledge and citizen preparedness. We found that 73% of the students felt their HRWS had been violated, primarily due to issues with access and availability. The other 27% did not see their HRWS as violated because they believed the water issues were not severe, and they still received water, even if it was only once a

day. This underscores the need for a stronger connection between the national context and students' daily lives.

The opinions expressed about the state of the HRWS in their communities primarily highlighted three key aspects:

- (i) The importance of adhering to HRWS recommendations to prevent adverse health impacts, ensure a stable water supply, and manage contamination.
- (ii) Acknowledgment of access, availability, and water quality failures, which indicate a breach of their rights.
- (iii) The importance of citizen involvement in water management. The least frequent responses targeted the authorities' poor law enforcement, disparities in water access favoring corporations, and citizens' lack of interest in water-related issues (Table 2).

The participants were asked to identify community issues in water management. They found that the most common problem was in the water distribution networks. They provided several examples of failures in access, metering, and service hours, which accounted for 52% of the reported issues. Eight percent of participants indicated the need for better water quality and acceptability from the municipal water service, as well as improvements in domestic hydraulic systems infrastructure.

Concerning solutions to the identified problems, the participants recognized two key priorities. The first was the renewal and maintenance of municipal hydraulic infrastructure, noted by 33% of participants. The second priority was training and effectively monitoring government employees responsible for municipal water management, with 25% of participants emphasizing this necessity. Other significant points that should be addressed were promoting water culture (3%) and enhancing industrial hydraulic infrastructure to prevent contamination or overexploitation of water sources (2%) (Table 2). The proposed measures to address the water crisis were as follows:

- (i) Transforming or mitigating polluting practices at all levels (26%).
- (ii) Raising citizens' awareness of the global water situation and the need to change current management (24%).
- (iii) Increasing citizen participation in water management to advocate for improvements and prepare management proposals (21%). Additionally, enhancing current governance to ensure monitoring, regulation, and compliance with water laws related to HRWS and transforming water education was mentioned to a lesser extent (7%). The data suggests that participants did not view themselves as agents of change through education.

3.2 Results of the self-assessment questionnaire on the perception of compliance with the HRWS within the home

The responses were categorized according to the compliance levels indicated in the self-assessment questionnaire (Figure 1). Participants who reported consistently receiving the service were

TABLE 3 Self-assessment questionnaire results on perception of community governance of the HRWS.

State compliance on HRWS	Frequency of responses (%)	Comments
Does the state currently guarantee HRWS? Explain	No 84%	Poor availability and intermittent flow.
Impact of poor HRWS enforcement in public health	Yes 99%	Damage to health due to lack of hygiene and drinkability.
Who should guarantee the HRWS? Why?	Government 88%	Ensure access through institutions such as Conagua with citizen support.
Is there equality in access and availability between citizens and companies? Justify.	No 93%	Companies have greater access and availability at a lower cost.
Is there government surveillance to prevent industrial pollution? Justify.	No 89%	There are environmental damages due to industrial pollution.
Is there a law and authority enforcement to remediation or mitigation of industrial contamination? Justify.	No 78%	There is a compendium of laws, but there is impunity in industrial contamination.
Is it important for citizens to participate in the management of water in their communities? Justify.	Yes 99%	It favors conservation of resources, demands more efficient management, citizens can make proposals.
Is there a possibility for citizens to get organized to defend their HRWS? Justify.	Yes 96%	Citizens should get organized to propose and improve water management and detect problems.

classified as good, while those who mentioned inconsistent or insufficient service were classified as poor.

Participants acknowledged that optimal adherence to domestic and local sanitation requires effective collection and proper disposal of solid waste, along with the treatment of wastewater. They felt that both home and industrial wastewater are suitably processed in municipal treatment facilities, provided there's a network linking their septic tanks to the municipal system.

Table 3 presents feedback regarding perceptions of water resource management. The results suggest that the government falls short of standards for ensuring water is accessible and available. Students feel that reliable access to water is uncertain since, in some locations, piped water is either unavailable or only flows sporadically. The quality of water is deemed unacceptable, as consumption can jeopardize health. Participants recognize that failing to meet specific criteria for household drinking water can negatively impact health, hygiene, and safety. Sixty percent (n = 120) indicated that someone in their household experienced gastrointestinal illnesses between one and five times per month.

They were asked whether the discomfort was related to the quality of the water. The most common response was that they did not know. The government is responsible for water management through institutions such as the National Water Commission (CONAGUA), the Secretariat of the Environment and Natural Resources (SEMARNAT), and the municipalities. In Yucatán, the Potable Water and Sewage Board (JAPAY) oversees public water services; this agency is the designated government body for these operations. Yet, no student had this awareness. They highlighted the common conviction that all citizens deserve equal opportunities concerning private initiatives. They observed restricted access to water resources, citing overuse and inconsistencies in the prices companies pay for water. Following their experience with industrial water pollution, the students noted that, although regulations are in place, there is a lack of enforcement by authorities. The penalties seem to fail to mitigate the effects of pollution. They referenced cases of visible environmental harm, yet the accountable companies persist in their operations and pollution without consequences. They recognized the importance of citizen participation in water management. They understood that active involvement in management could enhance citizens' awareness of their responsibilities regarding water management and empower them to demand and propose better alternatives to address management shortcomings. Examples of citizen participation included organized marches, identifying problems, and community suggestions for improvement made to their municipalities. Based on the evaluation of the overall condition of the HRWS, as illustrated in Figure 2, the following findings were made: (i) Municipal water management services are severely affected, with examples and descriptions of limitations in access and quality; (ii) citizens face disadvantages compared to private initiatives regarding access, availability, and affordability; (iii) there is a lack of accountability in established cases of industrial pollution. Despite acknowledging these limitations, 46% of participants regarded their HRWS as fair, while 40% rated it as good. Only 7% assessed it as "bad" and 5% as "very bad."

In comparing the current HRWS parameters, derived from official data and scientific studies, with students' perceptions as shown in Table 4, the categorization of service to citizens is as follows:

- (i) Good: when all conditions for the specified parameter are fulfilled.
- (ii) Regular: when some conditions are fulfilled.
- (iii) Bad: when the service fails to meet the criteria or is not received.

The students' feedback was categorized using consistent criteria based on the conditions under which they discussed the services linked to the HRWS. Their feedback was presented as percentages. Regarding accessibility, a significant portion rated it as good (60%). They struggled to identify issues related to the acceptability of domestic and municipal sanitation due to clearer discrepancies between actual conditions and perceptions. Eighty-four percent indicated a septic tank connected to a municipal treatment facility. Nevertheless, none of the towns where the schools are situated have sewage treatment infrastructure (CONAGUA, 2021). They reported that urban solid waste management was regular (55%). The

municipality provides an inconsistent garbage collection service, and the waste is dumped in a municipal dumpster that does not meet the minimum standards of a landfill as outlined in the Urban Solid Waste Norm 083-SEMARNAT-2021 (DOF, 2021; DOGEY, 2019). Acceptability was rated as good (51%). However, they do not drink piped water and report getting sick if they consume it (Table 4).

Students recognized that the government failed to ensure human rights for safe drinking water and sanitation (HRWS) and lacked effective monitoring, surveillance, and law enforcement (Wilder et al., 2020; García-Searcy et al., 2022). Nonetheless, the suggested enhancements primarily emphasized immediate access and availability, while offering limited focus on regulating polluting activities and overexploitation.

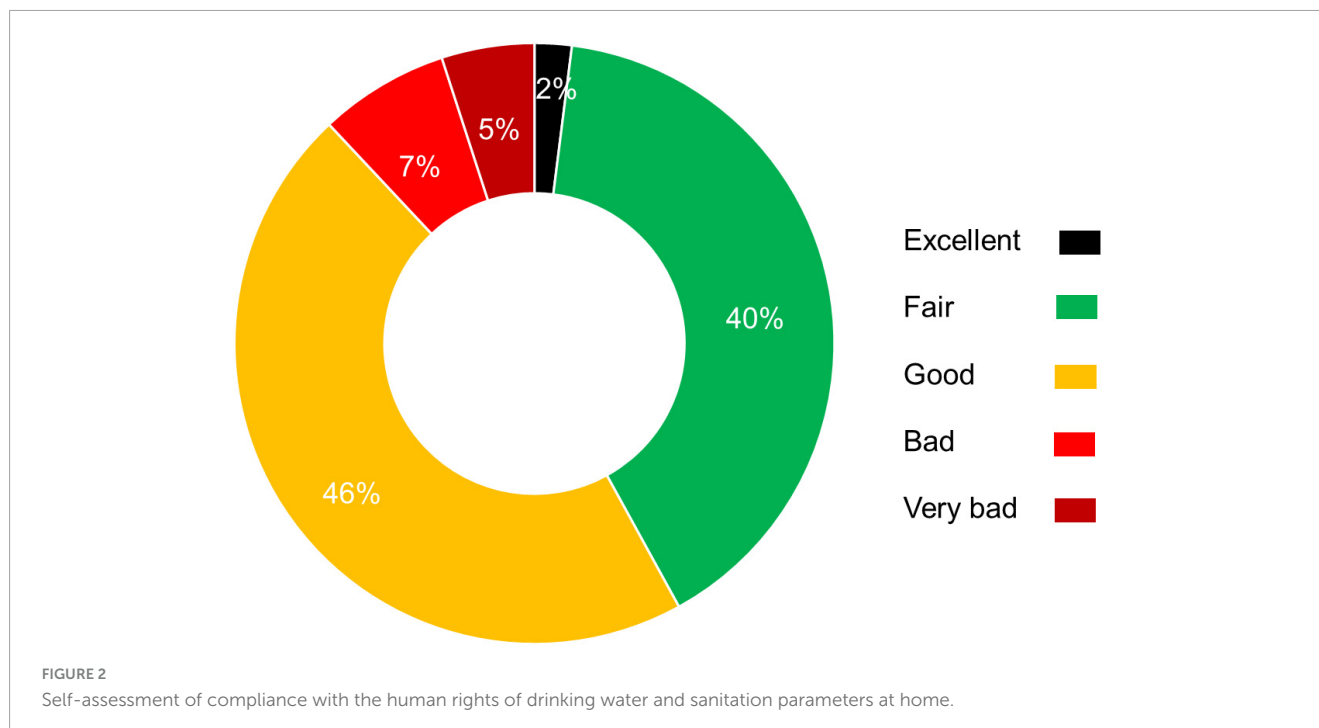
4 Discussion

Workshops and evaluations based on the competency model for teaching water and sanitation sustainability (Cebrián and Junyent, 2015; Cebrián et al., 2020) were effective tools (Ojeda-Barceló et al., 2009; Castle and McGuire, 2010) for understanding the thinking, contextualization, future vision, and values associated with the HRWS of participating students. Research has demonstrated that addressing these topics in the classroom offers the following benefits:

- (i) Identifying perceptions about environmental problems.
- (ii) Recognizing cognitive dissonance and psychological distance that can influence the development of pro-environmental behaviors.
- (iii) Identifying the contents to reinforce self-awareness to help students acknowledge their vulnerabilities and risks while fostering resilient behavior and critical thinking.

This exercise may empower future educators to be more assertive, critical, and proactive in managing children's education concerning the water crisis. The data from the community regarding HRWS (Table 2) reveal that participants were impacted by issues related to infrastructure failures, distribution challenges, and ineffective public water management. Nonetheless, their main focus was on access and availability. They did not recognize the broader implications of sanitation, encompassing domestic and agro-industrial water sanitation and urban solid waste disposal. Assuming current services are sufficient, it ignores the reality that these services fall short of the established Mexican standards (DOF, 2004) and the criteria for HRWS (UNGA, 2010).

The students were well-informed about the issues concerning community water management, such as its impact on the health of the ecosystem, the lack of accountability in the private sector, and the insufficient thoroughness of government agencies. However, they did not recognize the link between water quality and health. It is important to note that significant advancements in global health have stemmed from progress in sanitary engineering (Yu et al., 2014; WHO, 2023), yet the participants remain unaware of this fact. They were unable to observe that their homes lacked municipal wastewater systems (CONAGUA, 2021). This issue is closely tied to the karst system. Most residences utilize septic tanks,



with walls covered in faulty stone and cement lining. Much of the liquid waste seeps into the ground below. Cleaning septic tanks is a rare necessity. As a result, significant contamination of the aquifer has occurred, often unnoticed by residents (Febles-Patrón and Hoogesteijn, 2010; Martínez-Peña et al., 2013). Therefore, the widespread belief that every house is tied to a wastewater system leading to a treatment plant.

The reason students do not perceive any issues with their access to safe water and sanitation (HRWS) can be illustrated with an example. When water service is intermittent or the supply is inadequate (poor availability), people tend to store water in plastic containers. Although this practice compromises hygiene and water quality, it is not viewed as a problem. This is because individuals consider their situation normal, as it has always been that way, and they believe conditions are worse in other places, which makes them feel fortunate. Individuals might possess the information needed to evaluate their situation; however, in the absence of comparative benchmarks, they are unable to fully understand their circumstances or explore avenues for improvement (Corral-Verdugo et al., 2006; Fan et al., 2014; Bayu et al., 2020). A study by Ruiz-Garzón et al. (2021) in Spain found that students discussing sustainable development identified access to clean drinking water as essential for societal progress. They acknowledged the detrimental effects of inadequate availability and sanitation, demonstrating a desire for improved resource management. Unlike the participants in this study, the Spanish students benefited from strong environmental education, and their access to water, its quality, and sanitation were optimal, contributing to a higher quality of life. It's essential to compare what is right and desired, with what is wrong and unwanted. This lack of comparative ability can lead to inactivity and negatively impact human and ecosystem health (Hargrove et al., 2018; Sadoff et al., 2020; Mishra, 2023). People must have clearly defined well-being standards to identify flaws in their lives. Students

were more inclined to recognize and accept the global water crisis than to acknowledge their own vulnerability. The global water crisis is broadly acknowledged and accepted within society. Nevertheless, they struggled with critical thinking skills needed to question and comprehend how this crisis directly affects their community. Their lack of self-evaluation is evident, with only 11% acknowledging their circumstances in the context of HRWS. These results can be understood through two theories: (i) cognitive dissonance, in which individuals might regard the situation as favorable to avoid discomfort arising from unresolved conflicting beliefs (Thøgersen, 2004; Bosone et al., 2022), and (ii) psychological distance, wherein people perceive effects at a social rather than an individual level, thus minimizing their intention to act (Milne et al., 2000; Spence et al., 2012; Li et al., 2022). Psychological distance hinders critical thinking, as abstract ideas must connect with experienced reality. The students participating were unaware of their HRWS, normalizing gaps in their rights despite the educational process. Once these students become teachers, they will likely display the same behavior. Educators need the right tools and standards to motivate and engage students in learning about water management. Without these resources, social pressure and resistance to change may be insufficient. Therefore, students must receive proper education about HRWS (Nisbet and Gick, 2008; Ellerbrock et al., 2016; Tamar et al., 2021).

The proposed solutions sought to eliminate polluting practices and enhance public awareness of their role in community water management. Only 7% ($n = 263$) recognized the necessity of reforming industrial practices related to overexploitation, pollution, and significant lapses in regulation and accountability, emphasizing citizens as the main problem instead of addressing the administrative gaps at both the industrial and governmental levels (Nisbet and Gick, 2008; Spence et al., 2012). Notably, globally, 10% of water withdrawals are allocated for human consumption, while

TABLE 4 Comparison between current compliance with HRWS parameters in Yucatan and students' perception (most frequent response).

HRWS parameters	HRWS Yucatan Scientific and official information	Compliance categorization	HRWS Yucatan Students' perception	Students' categorization
Water accessibility inside the home	Water inside the home (40%–70% of homes). Storage systems because of intermittent flow (95% of homes) (INEGI, 2020).	Regular	Recognize access problems and use storage strategies	Good 60%
Water at home	Homes connected to the public water network (75%–95%). Intermittent service for days and hours (Guardiola et al., 2010, INEGI, 2020).	Bad	Normalization of intermittent flow through in-home storage strategies.	Fair 49%
Water with acceptable odor, taste, and color	Piped water has an unpleasant taste, bad smell, and sometimes turbidity. Excess or lack of chlorination is reported.	Bad	Piped water has acceptable conditions, but they avoid drinking it.	Good 51%
Potability of piped water	There are no municipal water treatment plants in Yucatan. Fecal coliforms, agrochemicals, heavy metals, etc., have been found in the aquifer. (CONAGUA, 2021; Hoogesteijn et al., 2015; Polanco-Rodríguez et al., 2022).	Bad	Do not consume piped water. Do not explicitly recognize that it is not drinkable. Do not relate the frequency of gastrointestinal diseases to the water quality.	Bad 99%
Bathroom inside the home	Bathrooms and sanitation systems that do not comply with regulations (Febles-Patrón and Hoogesteijn, 2010)	Fair	Having bathroom/s inside the home, are unaware of their wastewater treatment.	Good 84%
Municipal wastewater treatment	There are no operational treatment plants in the interior of the state, and less than 3% of the water extracted is treated (DOGEY, 2019; CONAGUA, 2021).	Bad	Students assume their bathrooms are connected to the municipal treatment plant network.	Good 80%
Municipal solid waste treatment	There are no landfills that comply with management regulations, Municipalities only have open dumps (DOGEY, 2019).	Bad	Intermittent garbage collection service is sent to the municipal open dump.	Fair 55%
Costs of bottled water	The average consumption of bottled water per Mexican home represents an expense of 4.5% per month of the average salary (Montero-Contreras and Gutiérrez, 2024). There is no data for Yucatan, but climatic conditions will probably increase it.	Bad	Bottled water represents an important expense	Bad 99%
Costs of piped water	Piped water costs 6 Mexican pesos/m ³ in fixed monthly fees, which does not exceed 3% of the minimum wage.	Good	Costs piped water do not represent a large monthly expense.	Good 57%

the remaining 90% is used by agriculture and industry (Oki and Kanae, 2006; Bayu et al., 2020).

Public policies and governance were the least emphasized topics (Fortner and Meyer, 2000). It is particularly noteworthy that the group overlooked the root causes of these issues, especially given the many instances of impunity and insufficient oversight by environmental authorities in the state. This environment of impunity creates a lawless atmosphere that prevents any shift in perspective (Sandoval-Díaz, 2020). Those who recognize these problems often feel overwhelmed and powerless in the face of such vast challenges. One potential solution could be integrating environmental values into group discussions, encouraging young individuals to engage actively in pro-environmental movements. This approach could emerge from the educational sector, where educators are vital. Teachers need to acknowledge the significant influence their roles can have on society (Lange and Dewitte, 2019; Shapira-Lishchinsky and Tsemach, 2014). Stressing this point to future educators is crucial, as they might not fully grasp the extent of their potential societal impact through their teaching work.

Teachers' beliefs and values regarding sustainability, nature, and water governance significantly shape their environmental

education approaches (Nisbet and Gick, 2008; Yli-Panula et al., 2023). Educators who identify strongly with environmentalism are likely to employ teaching methods that promote sustainable behaviors among their students (Tamar et al., 2021). Nonetheless, the effectiveness of their teaching can diminish if there is a mismatch between their beliefs and everyday practices (Waters-Adams, 2006; Ellerbrock et al., 2016). Incorporating insights from environmental psychology can provide a deeper understanding of how personal values affect educational engagement, and it can assist teachers in enhancing their influence as role models in advocating for sustainable practices (Lange and Dewitte, 2019).

Conducting studies like this is crucial to identifying the areas of educational programs that require strengthening. Participants in the study failed to recognize the significance of teaching practices aimed at enhancing water culture. Additionally, they did not fully acknowledge their potential as future agents of change capable of improving their students' overall quality of life (Fortner and Meyer, 2000). To our knowledge, no similar findings have been published in Mexico. This topic should be prioritized for future development, especially due to the serious environmental

challenges the country faces (Cockerill, 2010). The failure to recognize one's vulnerabilities hinders one's capacity for action, making it vital to train knowledgeable professionals who adhere to the principles of care and environmental justice (Kowasch, 2023).

5 Conclusion and recommendations

In this study, we advocate for actions that foster citizen engagement in water management via the educational system. These initiatives include (i) enhancing awareness of citizen participation mechanisms and legal rights, ensuring that both the public and educators are knowledgeable about organizations that oversee natural resources, (ii) highlighting the significance of various facets of the HRWS, extending beyond mere access and availability, as sanitation issues can lead to serious health and environmental consequences; (iii) offering environmental education for teachers to empower them as catalysts for social change; (iv) informing affected individuals about their rights and responsibilities, along with defense strategies for cognitive dissonance and psychological distance; and (v) utilizing electronic resources to tackle socio-ecological challenges, considering time and resource limitations, which can improve comprehension of environmental issues concerns.

Furthermore, cognitive dissonance could be addressed using activities designed to prompt reflection on the long-term consequences of water crises. This strategy aligns with public policies, integrating water topics within teacher training, complete with dedicated modules and chances to contemplate water governance policies. These initiatives aim to enhance ongoing training and build partnerships among academic institutions, governments, and local communities to encourage sustainable learning action.

These findings were communicated to educational institutions to facilitate the implementation of these proposals, emphasizing on the recognized gaps and offering instructional resources. Additionally, the digital materials used in the workshop are publicly accessible. Furthermore, CONAGUA and national and state Public Education Secretaries were approached to discuss the results and suggest establishing a course focused on water culture for teachers, covering subjects absent from the existing educational curriculum. The proposal was embraced and is currently under consideration for development.

Through these actions, trainee students could acquire a fundamental understanding of Yucatan's intricate water resource issues. Future teachers would need further professional development to analyze, tackle, and manage environmental challenges effectively. With increased familiarity with the subject, student trainees should be able to incorporate these ideas into their teaching, promote their inclusion in curricula and textbooks, and help cultivate informed, engaged, responsible, and proactive citizens for the future.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comité de Bioética para la Investigación en Seres Humanos del Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (COBISH). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

AL-S: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft. MG-R: Methodology, Resources, Supervision, Validation, Writing – review and editing. LF-N: Formal Analysis, Methodology, Resources, Supervision, Validation, Writing – review and editing. AH-R: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1470636/full#supplementary-material>

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