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# A teaching proposal on the new water culture for students aged 14–15: design, application and evaluation in a Colombian context

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Education is key for teaching citizens to be aware of the value of water and the importance of using it sustainably. This work analyses the effects of a teaching proposal called *Únete a la Nueva Cultura del Agua* [Join the New Water Culture] for students aged 14–15 in a Colombian context (<https://hdl.handle.net/10481/81284>). It was applied in Social and Natural Science classes over 10 two-hour sessions. It was evaluated through: (a) Pretest-postest questionnaire; (b) follow-up questionnaires on the proposal that included self-evaluation, co-evaluation and hetero-evaluation on the part of students; and (c) student workbooks. The results showed the strengths and weaknesses of the proposal. It is concluded that there is a good correspondence between the strong and weak points of the proposal and the contents of the tasks that received the highest and lowest scores, respectively, revealing the associations between knowledge and perceptions. These associations are corroborated with the entries in the student workbooks following the end of the teaching proposal.

## KEYWORDS

sustainability, water, compulsory education, teaching proposal, science in context

## 1 Introduction

Life on Earth as we know it was made possible thanks to the existence of liquid water, and it is the lack of this very water that is endangering its subsistence. It is clear today that we cannot suppose there is an almost infinite availability of water on the planet ([Naciones Unidas, 2021](#)), and that we must therefore draw attention to the many natural, cultural, economic, historical and emotional dimensions of water heritage ([Hernández, 2014; Arrojo, 2021](#)).

Demand for water has accelerated over the last 100 years by a factor of six, and has continued to do so at an annual rate of approximately 1% from the 1980s ([AQUASTAT, 2010](#), as cited in [Naciones Unidas, 2012](#)). Scenarios such as that which took place in Cape Town, South Africa, with ‘Day Zero’ in 2017 and 2018, have been predicted in at least 25 countries ([World Resources Institute \[WRI\], 2023](#)), and can appear in any place on the planet, because as the demand for water increases, its depletion is also accentuated ([Naciones Unidas, 2021](#)).

In Colombia, there are eight times more fresh water resources *per capita* than the global average ([World Bank, 2022](#)), but this does not mean they are well managed. Examples of water

wastage include the huge officially recognised figure of 40.2% of drinking water that is lost as unaccounted-for (Superintendencia de Servicios Públicos Domiciliarios de Colombia, 2020) and the fact that only 48% of residual water is purified (Ministerio de Vivienda Ciudad y Territorio de Colombia, 2022). These problems can reach extreme proportions in some areas in the interior of the country (Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia, 2019).

The overriding question regarding this issue is: How can a situation with these characteristics be confronted, a reflection of the cultural approach through which humanity has (under)valued, (badly)used and (badly)managed water over thousands of years? (Vilches and Gil-Pérez, 2009; Pérez, 2015; Arrojo, 2021). Technological progress is evidently important (let us recall water desalination, regeneration and reuse, the modernisation of irrigation, etc.), but it would be a fallacy to believe that this alone can address the complexity of the water problem (Fundación Nueva Cultura del Agua, 2023). There is a need for a comprehensive interdisciplinary perspective led by affected individuals who possess the knowledge to provide solutions.

In this search for answers, education plays a crucial role in teaching citizens about water (Hernández, 2014) and its many values (Pérez, 2015). It involves connecting students to the making of better informed decisions and to the appropriation of more sustainable water consumption patterns (Naciones Unidas, 2021). Learners must recognise they are part of the problem and the solution (Jaén et al., 2014; Khiri et al., 2023), upon seeing in the water crisis possibilities of change for a better future.

The purpose of this work is to describe and evaluate the implementation of a teaching proposal that promotes the construction of a new mentality in the approach of the relationship with water, from the areas of Natural Sciences and Social Sciences, aimed at final year students of compulsory education in Colombia (aged 14–15). The teaching proposal is called *Únete a la Nueva Cultura del Agua* [Join the New Water Culture] and, although it focuses on the context of Bogotá and Colombia, it can be adapted for implementation in other contexts and populations.

## 2 Theoretical framework

### 2.1 Habitual teaching on water

Inquiring into prior conceptions held by Spanish students on water, Marcén (2006) finds they are aware of its importance for living beings, for health and personal hygiene, and its usefulness in daily life; furthermore, they possess considerably more knowledge, such as the existence of different types of water, the existence of a cycle that keeps it in continuous movement, the need to manage it appropriately, and so on. These findings largely coincide with those of Havu-Nuutinen et al. (2018) in Finland.

In contrast to the foregoing, authors such as Castelltor et al. (2014), Liefänder et al. (2016) and Pozo-Muñoz et al. (2023) find that many students are unaware of the impact human activity has on the water cycle, or of its consequences on both the quantity and quality of the resource.

Water pollution is a topic that has been referenced considerably by scholars according to Marcén (2006), Jaén et al. (2014), and Pozo-Muñoz et al. (2023), among others, who indicate that students identify pollutants such as soap and toothpaste, but not domestic waste such

as ‘fats and oils, organic matter, solid waste, detergents and cleaning products’ (Castelltor et al., 2014, p.56).

Moreover, according to Castelltor (2015), students lack knowledge on the circulation of water in their own cities, are unsure about where water comes from, do not conceive of any type of purification before consumption and fail to establish differences between purification and treatment. Hernández (2014) finds that students are unaware that all of the water that reaches their homes is drinkable, even that which enters the cistern, and that once used it flows to a sewer system where it must be treated before being returned to the environment.

To summarise, it is observed that a large number of the conceptions discovered in students incline towards a more traditional water culture, in which water resources are not altered by human beings in such a transcendental way.

These conceptions can be reinforced by the cultural image transmitted in school through textbooks and official curricular content (Marcén and Cuadrat, 2012; Pozo-Muñoz et al., 2023). In a study on both Spanish and Colombian school texts (Benarroch et al., 2022a), it was found they maintained an amorphous posture and did not comprehensively advocate a water culture that promotes sustainability.

The difficulties students have with water, its usage and consumption can be exacerbated due to lack of knowledge on the part of their teachers (McCarroll and Hamann, 2020; Kwee and Dos Santos, 2023). Benarroch et al. (2022b) and Ramírez-Segado et al. (2023) found that future educators in Spain lack optimal knowledge for deploying useful teaching-learning processes in order to raise awareness and evaluate solutions adapted to the new era. They suggest their main source of information comes from the media and not academic training.

Thus, although there is evidence of a positive transformation of teaching about water, it is still frequently the case that water is addressed in a decontextualised way, without relevance for students (Sammel, 2016) and it is presented as a natural resource subject to a cycle that is also natural and not threatened by human presence (Sammel, 2016; Amahmid et al., 2018; Martínez-Borreguero et al., 2020).

In this vein, studies such as those by Marcén and Cuadrat (2012), Castelltor (2015), Amahmid et al. (2018), Benninghaus et al. (2018), Scoarize et al. (2021), Castro-Velásquez and Benarroch (2023), and Pozo-Muñoz et al. (2023), among others, argue that when interdisciplinary context-based teaching approaches are implemented, with a predominance of argumentation and inquiry, there is a considerable improvement in learning.

This study supposes that the acquiring of scientific knowledge, values and habits that promote the sustainability of water heritage from school can improve through the sequencing of teaching activities focused on those proposed by the New Water Culture.

### 2.2 The new water culture and the premises of the teaching proposal

For the design of the teaching proposal on water, there was a consideration of the need for a starting theoretical framework and it was decided to adopt that comprising the so called New Water Culture (NWC), which addresses the topic of water from the multiple perspectives of ethical, environmental, social, economic, political and emotional values integrated into water ecosystems

TABLE 1 Theoretical contexts that distinguish between old water culture and new water culture.

Contexts	Old water culture	New water culture
1	Water imbalance Water is scarce. The fresh water on Earth is insufficient. Water scarcity is due to water imbalance. Water is an unlimited and renewable resource.	Natural balance Water is not scarce; if we look after it, it will be sufficient. Occasional water scarcity is due to mismanagement and abuse in its use and consumption. Water is a renewable resource when its use, treatment, liberation and flow are carefully controlled. Otherwise it is a non-renewable resource.
2	Water as a productive factor Water is a basic resource. Water as a commodity, an economic resource.	Water as an eco-social asset Water has different functions; a very small part is a basic resource, but all of it has a heritage value. Water is not only an economic asset but is also fundamental to the survival and the future of our planet.
3	Water governability The responsibility for water falls to institutional leaders and governments. Traditional water management requires urgent changes.	Water governance Responsibility for water falls to all citizens. Educational programmes are required, starting in schools. The sustainable management of water is possible and there are now specific proposals.
4	Supply management It is necessary to increase the amount of fresh water available. Hydraulic works (reservoirs, transfers, desalination plants, etc.) are necessary to obtain more water.	Demand management We must reduce consumption rather than attempt to obtain more water. Hydraulic works are harmful to the environment. It is better to concentrate all efforts on controlling water demand.
5	Cost–benefit The water tariff regime does not distinguish between vital water and other functions of water. Polluters do not pay.	Cost-effectiveness The water tariff regime must distinguish between vital water and other functions of water. Polluters pay
6	Water as a human right Water is a human right that must be guaranteed by government. There are populations that lack vital water; governments must assume responsibility.	Water as a human duty Only a small proportion of water is vital water. The rest have obligations (responsibility for savings and costs). There are populations that lack vital water. We must all assume responsibility.
7	Consumerism Water saving is not a priority. Consumption of goods and eating habits do not affect water consumption.	Responsible consumerism Water saving is a priority at all levels (domestic, agricultural, industrial, etc.) Consumption of goods and eating habits are closely related to water consumption. We must be responsible consumers.

Taken from Benarroch et al. (2021, 2022a).

(Vilches and Gil-Pérez, 2009; Fundación Nueva Cultura del Agua, 2023).

Benarroch et al. (2021) summarised, in seven contexts, the differences between the traditional vision of water, referred to as the old water culture, and the vision from sustainable development promoted by the NWC. These are shown in Table 1.

A number of methodological and strategic principles were also adopted. These were, in essence:

The proposal had to be contextualised both at individual and large scale level (from local to global), involving the promotion of changes in individual behaviours, customs and lifestyles given that, as irrelevant as they may appear, when multiplied by the millions of people around the world, they can translate into substantial changes (Vilches and Gil-Pérez, 2009). Teaching in context has the objective of preparing young people as citizens who are critical and able to make fundamental decisions, emphasising relationships between scientific content and socio-cultural aspects (Pérgola and Galagovsky, 2020; Khiri et al., 2023).

It was necessary for the proposal to mobilise emotions in students, given the importance of the role played by interest, curiosity,

imagination and eagerness to interact and ask questions in school learning (Harlen, 2013; Jiménez-Liso et al., 2020).

Given the strong interdisciplinary nature of the water problem, there was a need for the proposal to recognise the contributions that could be incorporated from different curricular areas. Nevertheless, and to be realistic, it had to at least integrate the areas of Natural Sciences and Social Sciences, which are those most directly involved in this cultural transformation process of teaching about water (Tan, 2020; Castro-Velásquez and Benarroch, 2023).

In terms of resources, priority is afforded to those that promote the development of critical models in relation to socio-scientific matters. Press releases particularly stand out in this regard, as they show differences of opinion that are useful for discussing water related controversies (Vilchez, 2009; Díaz, 2019).

As part of the proposal different ways of grouping should be favoured. In this way, students approach knowledge through individual reflection, interaction and teamwork, in the same way as scientists (Sanmarti and Márquez, 2017; Raviv et al., 2019).

TABLE 2 Items distributed in the blocks comprising the pretest-posttest questionnaire and their relationship with the seven theoretical contexts of the NWC and the tasks from the proposal.

Block	Items	NWC theoretical context	Teaching proposal tasks
Block 1: Water resource protection	1, 2, 3, 4, 5, 6, 7, 8, 9	1	1
Block 2: Water dimensions	10, 11, 12, 13, 14	2, 3	2, 7
Block 3: Water management	15, 16, 17, 18, 19, 20, 21	4, 5	4, 5, 6, 8, 9
Block 4: Personal actions associated with water	22, 23, 24, 25, 26, 27	6, 7	3, 8, 9, 10

Adapted from Benarroch et al. (2021).

## 3 Methodology

### 3.1 Context and participants

The experience took place in a secondary school, in Engativá (Bogotá, Colombia), over the months of June and July 2022. Engativá is located in the north west of the city, an area where the basins of the Salitre and Bogotá rivers meet (Secretaría Distrital de Ambiente de Bogotá, 2020). This locality is home to the only waste water treatment plant in the capital, with the capacity to deal with 30% of the city's water. Engativá is remarkable for its high level of biodiversity and water availability; however, demand for water is high and it shows marked problems relating to pollution (Secretaría Distrital de Ambiente de Bogotá, 2022).

The single group that was the object of study comprised 37 students (49% girls and 51% boys) from the last year of compulsory education, aged between 14 and 17 (average = 14.9, SD = 1.00). The students came from low (32%) and middle (68%) socio-economic strata.

The habitual teachers of the Social Sciences and Natural Sciences subjects of the study object group voluntarily agreed to implement the proposal in the classroom. These educators were aged 36 and 39 and had teaching experience of 12 and 16 years, respectively.

### 3.2 Procedure

*Únete a la Nueva Cultura del Agua* was structured into 10 two-hour tasks. The teaching proposal is available at: <https://hdl.handle.net/10481/81284>. It mainly comprises one teacher's book and one student workbook.

The teaching proposal was shared with the two participating teachers and their suggestions were gathered in the final product. It was then presented to the students, requesting their participation. Their participation was corroborated with the informed consent of their parents.

A mixed quasi-experimental single group pretest-posttest study was developed, based on the design, implementation and evaluation of the learning sequence. The statistical analyses were carried out with the program IBM SPSS version 25.

### 3.3 Instruments

The monitoring and evaluation of the proposal should favour summative and formative assessment. For the former, a pretest and posttest questionnaire was used. For the latter, a monitoring

questionnaire was designed for each session, generating a total of 10 monitoring questionnaires, via which students were asked for an assessment of their own work (self-evaluation), of the work of the classmates in their small group (co-evaluation) and of the work of the teacher and class materials (hetero-evaluation). There is also an analysis of the student workbook entries.

#### 3.3.1 Pretest and posttest questionnaire

The questionnaire proposed by Benarroch et al. (2021) was used, whose objective coincided in terms of inquiring into different cultural questions related to the water management, saving and consumption and, furthermore, boasted solid quality criteria in terms of validity and reliability (Benarroch et al., 2021). Nevertheless, it was necessary to adjust the questionnaire to the contexts of the Bogotá students. To do so, a pilot test was carried out, in which we verified that terms such as 'diversion' and 'desalination plant' were not known by the students. Consensus was reached on these adaptations with the authors of the initial questionnaire.

The instrument that was finally applied maintained the original structure: 27 items with a total of 71 variables that it was necessary to respond to according to the degree of agreement on a Likert-type scale of 1 to 4. For the statistical analysis, the negative items were recoded and identified with an 'i' after the item number.

An instrument reliability study was carried out, revealing a Cronbach's alpha coefficient of 0.771 for the pretest and 0.879 for the posttest.

The 27 items of the questionnaire were classified into four blocks, associated in turn with the 10 tasks that comprised the proposal and the seven contexts defined in the theoretical framework, as described in Table 2.

Block 1 studies the situation of the water resource on the planet, in Colombia and in remote regions of the country such as La Guajira; Block 2 inquiries into the dimensions of water (as an economic resource, or a social, environmental and productive asset); Block 3 deals with water heritage management via control of demand or increase of supply; and Block 4 addresses water saving and its indirect consumption via consumerist behaviours and eating habits (Benarroch et al., 2021).

A variable denominated Global was created to analyse the general results of the questionnaire, as well as the variables of each of the blocks (Block 1, Block 2, Block 3 and Block 4), which group the items of each block. After confirming that the results did not adjust to a normal distribution, we resorted to the Wilcoxon non-parametric signed rank test to determine whether the distribution of the ordinal variables measured in the pretest and the posttest were significantly different between the two measurements (George and Mallery, 2019). The non-parametric

tests were carried out with a bilateral asymptotic significance level of 95% ( $\alpha = 95\%$ ,  $p < 0.05$ ).

### 3.3.2 Monitoring questionnaires of the teaching proposal

The 10 questionnaires are found on pages 125 to 134 of the teacher’s book, contained in the link to the proposal (<https://hdl.handle.net/10481/81284>). The students responded according to their level of agreement on a Likert-type scale of 1 to 4. In addition, they assigned a numerical score between 1 and 4 to these dimensions.

In this case the reliability study of the monitoring questionnaires revealed a Cronbach’s alpha of 0.989, which indicates an excellent reliability according to [George and Mallery \(2019\)](#).

### 3.3.3 Student workbook

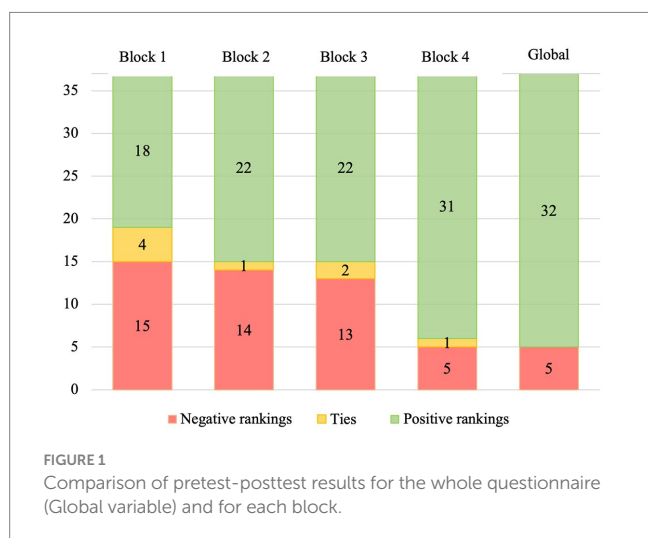
Each student received a workbook with the learning objectives, the description of the topic and the activities of the 10 tasks. This material can be found on the teaching proposal link (<https://hdl.handle.net/10481/81284>). This article deals solely with the analysis of the responses to task 10, the last in the sequence, for the purpose of a qualitative inquiry into the learning of the students through their text production.

## 4 Results

### 4.1 Results of the pretest-posttest questionnaire

#### 4.1.1 Overall results

The *Global* variable shows significant differences between pretest and posttest ( $p < 0.01$ ). As shown in [Figure 1](#), for this variable, represented by the last column, 32 students presented improved scores in the posttest (positive rankings), compared to five in which they were poorer. There were no ties. Moreover, it is shown that the best results are obtained in block 4, followed by blocks 2 and 3; finally, the worst results are obtained in block 1.



#### 4.1.2 Analysis of teaching proposal strengths

In this section the strengths of the teaching proposal are analysed, extracted from those items that, having low results in the pretest, show a significant improvement in the posttest. [Figure 2](#) shows the 17 items that reveal this behaviour. These significant improvements represent knowledge that is more consistent with that put forward in relation to the water sustainability of the NWC. They are thus indicators of the strengths of the teaching proposal.

[Table 3](#) describes the statements for the 17 items that represent the strengths of the proposal.

*Block 1. Water resource protection.* As shown in [Figure 2](#), item 5 reveals a greater knowledge in students as regards reservoirs, transfers, desalination plants and dams, hydraulic facilities that obtain more water for humans.

*Block 2. Water dimensions.* The students show better results for the statements that inquire into the environmental damage of facilities and infrastructures used to obtain greater quantities of water (item 11) and specifically regarding transfers (item 14a).

*Block 3. Water management.* Students, in the posttest, were more aware of the fact that Bogotá residents from higher socio-economic strata consume more water than those from lower strata (item 21). Furthermore, they have greater knowledge of the urban water cycle. For example, they show more agreement on water used in the city, after it is treated, being used down river as water to irrigate crops (item 18c). Also important is the slow improvement on referring to the fact that both water that reaches homes (item 19) and that which leaves them after its use (item 20) require some kind of treatment. They also understand to a greater extent that the water they use at home originates from the region’s uplands (item 17b) and its reservoirs and lakes (item 17d).

*Block 4. Personal actions associated with water.* Attention may be drawn to the improvement in the results of the items in this block, which relates water usage with consumerism and food. Among these, particularly noteworthy is the saving in water from consuming less meat (item 25f) and more food from vegetable origins (item 25c), along with reducing purchases of clothes (items 25e and 27a) and electronic devices (item 27b). In the same vein, they coincided in saving water at an urban level with the elimination of golf courses (item 26e) and private swimming pools (item 26f), and adapting crop types to water availability (item 26b).

#### 4.1.3 Analysis of teaching proposal weaknesses

This section analyses the weaknesses of the teaching proposal, extracted from the items that, having poor results in the pretest, continued to do so in the posttest. [Figure 3](#) shows the 13 items that reveal this behaviour. In the case of two of them, their results are even significantly worse in the posttest than in the pretest.

[Table 4](#) shows the statements of the 13 items that represent weaknesses of the proposal. These weaknesses should be understood as opportunities for improvement.

*Block 1. Water resource protection.* The students do not show improvement in six statements in this block. Therefore, there is a prevalence of the tendency to consider that the scarcity of water is due to natural water imbalance (items 2i and 3) and it is not caused by humans (item 6i), be it at world level (item 1), Colombia (item 8ai) or regions such as Alta Guajira (item 9ai).

*Block 2. Water dimensions.* The items in the second block do not show characteristics that can be associated with weaknesses.

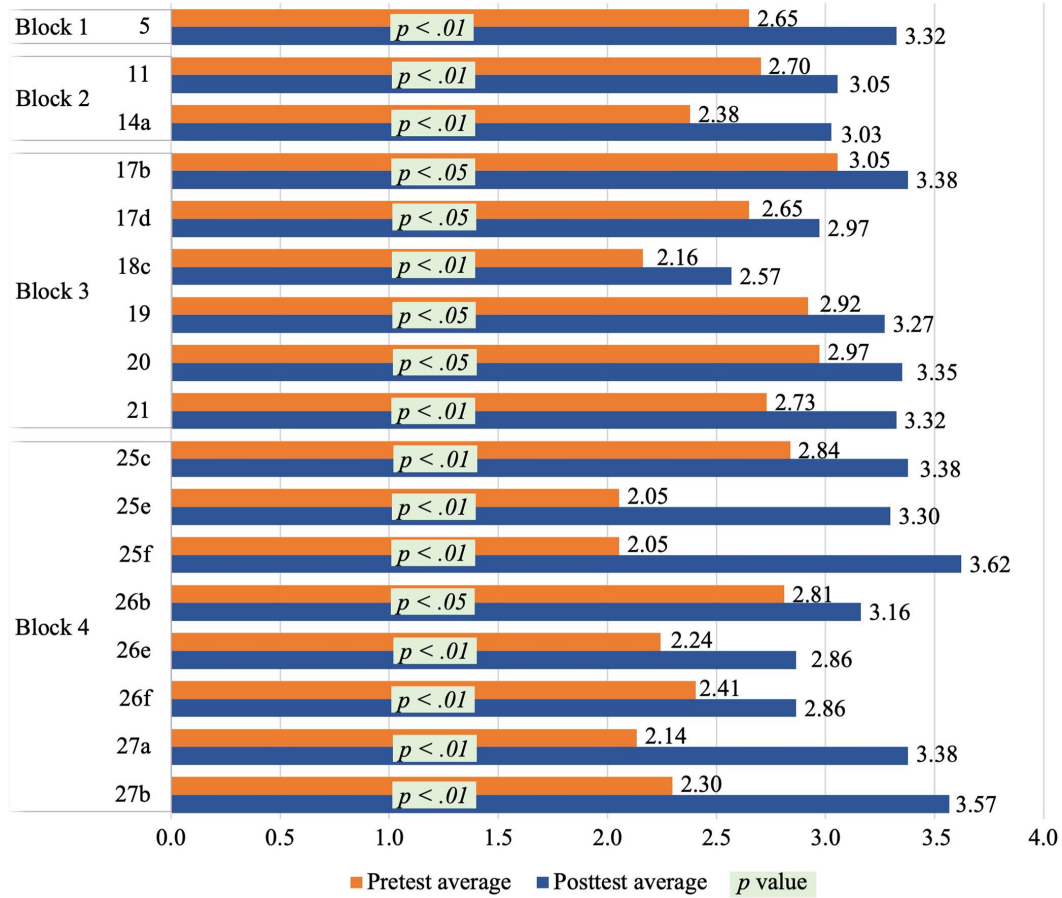


FIGURE 2 Distribution by blocks of content from the items that represent the strengths of the teaching proposal.

TABLE 3 Items with significant improvements between the pretest-posttest ( $p < 0.05$ ) identified as strengths.

Block	Item	Statement
1	5	<i>I have heard of hydraulic facilities (reservoirs, transfers, desalination plants, dams, etc.) which permit greater quantities of water to be obtained for human beings</i>
2	11	<i>The facilities and infrastructures used to bring greater quantities of water to human beings damage the environment</i>
	14a	<i>The following solutions that are normally used to obtain the water we consume damage the environment: a. Transfer water from some rivers to others via channels constructed by humans</i>
3	17b	<i>The water I use at home comes from... b. From the region's wet uplands</i>
	17d	<i>The water I use at home comes from... d. From reservoirs and lakes</i>
	18c	<i>The water we have already used goes... c. To water for crop irrigation, after its treatment</i>
	19	<i>Before getting to my home, water is treated in some way</i>
	20	<i>The water that leaves my home must be treated in some way</i>
	21	<i>Water consumption in Bogotá in stratum 4, 5 and 6 is considerably higher than consumption in stratum 1, 2 and 3</i>
4	25c	<i>We could save water in households... c. Consuming food of predominantly vegetable origin</i>
	25e	<i>We could save water in households... e. Buying fewer clothes</i>
	25f	<i>We could save water in households... f. Eating less meat</i>
	26b	<i>We could save water in our urban environment... a. Adapting crop types to water availability</i>
	26e	<i>We could save water in our urban environment... e. Eliminating golf courses</i>
	26f	<i>We could save water in our urban environment... f. Eliminating private swimming pools</i>
	27a	<i>The following actions affect water availability: a. Buying lots of clothes</i>
	27b	<i>The following actions affect water availability: b. Frequently changing smartphone, tablet, computer...</i>

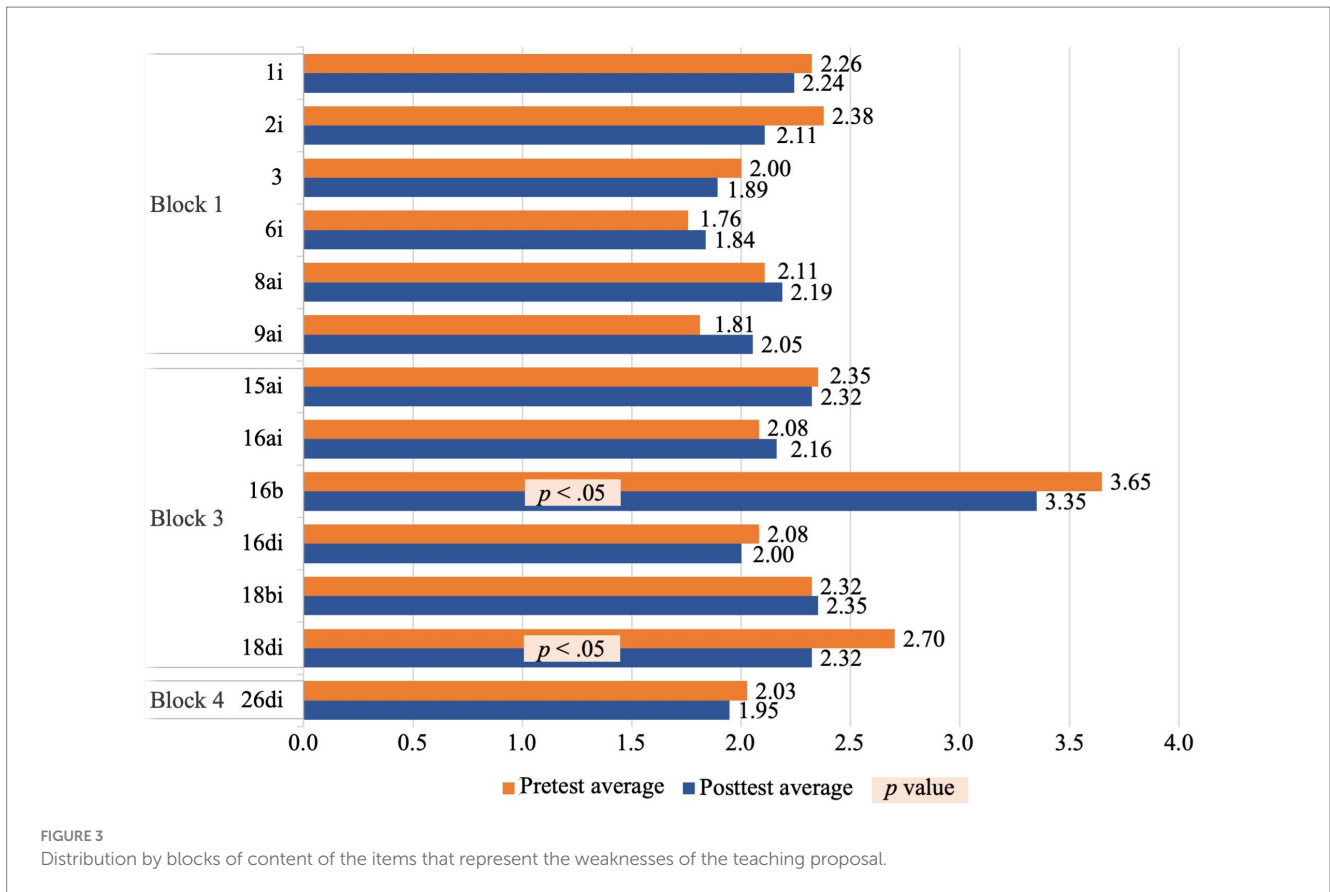


FIGURE 3 Distribution by blocks of content of the items that represent the weaknesses of the teaching proposal.

TABLE 4 Items that represent the weaknesses of the teaching proposal.

Block	Item	Statement
1	1i	The fresh water on Earth is insufficient
	2i	Water scarcity is due to water imbalance, as while there are some territories that are very wet, there are others that have very little water.
	3	Fresh water is not scarce. There is enough of it for the inhabitants of the Earth
	6i	There are zones that suffer degradation of their terrain due to acidity, drought or erosion generated by humans, which require water from other zones that have greater water resources
	8ai	The main problems affecting water in Colombia are: Scarcity
	9ai	The main problems affecting water in the remotest regions of the country, such as Alta Guajira are: Scarcity
3	15ai	If you were in charge of water management in Colombia, you would opt to... Build more water reservoirs, to guarantee supply
	16ai	If you were in charge of water management in the remotest regions of the country, such as Alta Guajira, you would opt to... Build a desalination plant that removes salt from seawater to make it drinkable
	16b	If you were in charge of water management in the remotest regions of the country, such as Alta Guajira, you would opt to... Promote water saving
	16di	If you were in charge of water management in the remotest regions of the country, such as Alta Guajira, you would opt to... Build more reservoirs
	18bi	The water we have already used goes... In its entirety into streams and rivers
	18di	The water we have already used goes... Into drinking water, after treatment
4	26di	In our urban environment, we could save water... Manufacturing essential products instead of importing them

Block 3. Water management. Faced with the hypothetical case of being in charge of water management in Colombia, the students would opt to build more reservoirs of water to guarantee its supply (item 15ai). A similar situation occurs when they are in charge of water management in remote regions such as Alta Guajira, given

they opt to build a desalination plant (item 16ai) and more reservoirs (item 16di) to increase the supply of drinking water. Here it is convenient to point out that in items 11 and 14a the students demonstrated their knowledge of the damage caused by these infrastructures.

Item 16b reveals significant negative differences, which implies that the students, following the teaching proposal, are more aware of the development needs of territories such as Alta Guajira and consider that water saving in them should not be a priority. Another item that shows inverse results is 18di, to which it is considered that waste water from the city be used as drinking water following treatment.

*Block 4. Personal actions associated with water.* The strategy that least favours water saving according to the students is to increase imports of essential products instead of manufacturing them at local level (item 26di).

### 4.2 Results of the teaching proposal monitoring questionnaires

The students, upon finalising each session: (a) self-evaluated their work, (b) coevaluated their classmates (c) hetero-evaluated the teacher, (d) the class and the activities. Figure 4 shows the averages of the four dimensions evaluated for the 10 tasks and their average as a whole. The left-hand columns result from the Likert-type scale and those on the right from the numerical classifications. All of the scores exceed the theoretical average (2.5). At a general level, the students gave better scores to the teacher, classes and activities; then the work of their classmates and, lastly, their own performance.

The laboratory water analysis practical (task 8) was the most highly scored and classified task of the whole sequence. This is followed by task 6, which addresses the aqueduct and sewer system of Bogotá. The task with the lowest average scores in the Likert-type scale was task 1, which studies supposed water imbalance compared to the natural balance of water.

### 4.3 Results extracted from the student workbooks

Task 10 is the final task of the teaching proposal. In it, students were firstly asked to suggest three strategies that encourage responsible consumption and water saving, both in their local environment and on a large scale. They were required to indicated how they would be implemented, how frequently and which agents would be involved.

The students produced a total of 99 initiatives. The majority implied a reduction of consumption for an indirect water saving (52.5%); another not inconsiderable percentage (42.5%) were proposals for direct water saving. The remaining 5% covers five proposals that argue for control of waste and pollution through economic cost. The strategies mainly involve the family group (79.7%) and students as individuals (16.5%), with only the other 3.8% involving other households or relations.

Initiatives for reducing weekly meat consumption particularly stand out. It is proposed that meat be replaced by other types of food whose production requires less water usage (Figure 5). Moreover, with the aim of reducing the consumption of electronic devices and other goods, such as clothing, it is suggested they be better cared for to favour more prolonged use (Figure 6). A single strategy proposes the recycling of materials (plastics and paper) as an indirect water saving measure. All of these initiatives that imply indirect water saving are now in the knowledge of these students and they must be attributed to the learning afforded by the teaching proposal.

The strategies for direct water saving are focused on restricting personal and domestic water consumption, and recycling water used in the home or rainwater. Although the former were initiatives associated with knowledge students already held in the pretest, the latter are products of the learning acquired from the teaching proposal.

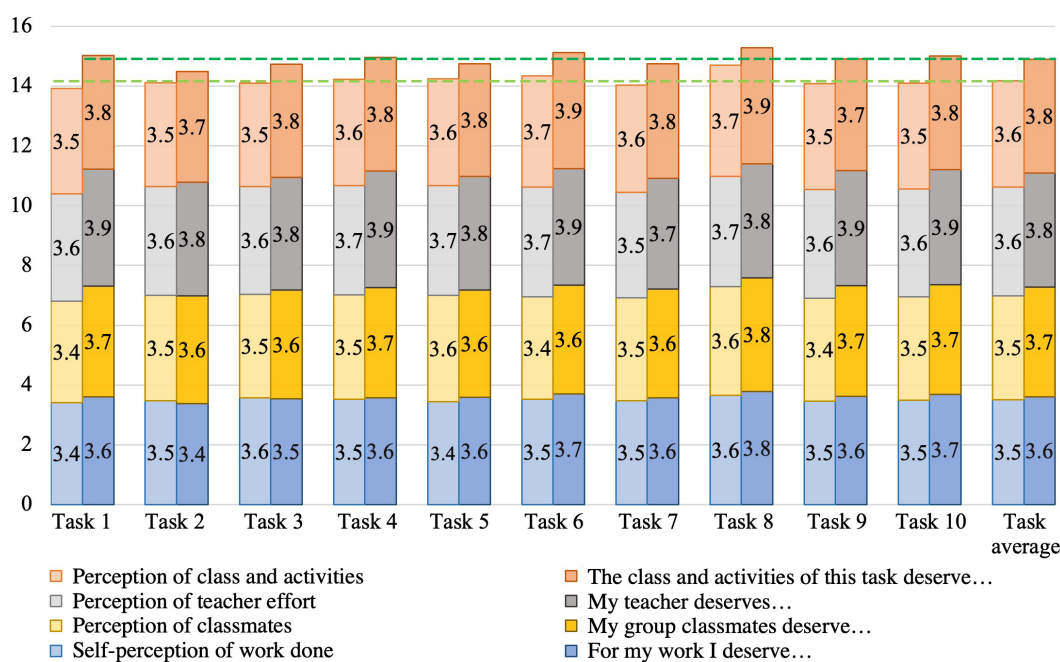


FIGURE 4 Average scores and classifications of self-evaluation, co-evaluation and hetero-evaluation of the students for the four dimensions considered. The final column represents the average of the teaching proposal as a whole.



Reducir el consumo de carnes para no seguir generando tanto consumo en la ganadería, como 1 o 2 veces a la semana. Las involucradas serían yo y mi mamá.

FIGURE 5

Proposal for indirect water saving by a student, through the changing of eating habits. Reduce meat consumption in order not to generate so much consumption in livestock, eat 1 or 2 times a week. Me and my mother would be committed.

No cambiar de smartphone a cada rato y más bien cambiarlo cada 5 o 6 años, estaremos implicados mi familia y yo.

FIGURE 6

Proposal for indirect water saving by a student, through the responsible consumption of goods. Do not change your smartphone so often and change it more like every 5 or 6 years, my family and I would be committed.

Vivimos en una sociedad a la cual no le importa el gasto de agua si es por tener el último celular, se debería ser más consciente ya que el agua es un recurso primordial para el ser vivo en general, debemos tener en cuenta el gasto y las consecuencias que conllevan a este mismo.

FIGURE 7

A reflection made by a student at the end of the teaching proposal related to learning from Task 10. We live in a society in which water consumption is not important if it is to have the latest mobile phone, there should be greater awareness as water is an essential resource for living beings in general, we must take its use into account and the consequences that it has.

As well as the proposals for direct and indirect water saving, the five proposals that argue for the control of wastefulness and pollution via economic cost are particularly interesting. Three of them imply *not mixing (used) oil with water and taking it to authorised collection points* to avoid domestic waste pollution via the sewer system. These links between waste and water saving are also products of the learning gained through the teaching proposal.

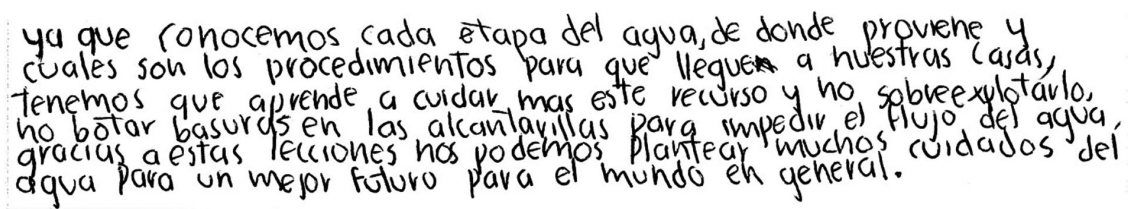
Following the end of task 10, to finish the teaching proposal, students were asked to reflect on current development models. The highest percentage (67.7%) focuses on learning also associated with task 10 (see Figure 7 as an example), but another not inconsiderable 32.3% relates to fundamental reflections on content addressed in other spaces of the teaching proposal (see Figure 8 as an example).

It is observed that students focus their reflections mainly on criticism of current society and its development model, where consumerism creates an indirect and unsustainable consumption of water, as also shown in the strengths detected in the pretest-posttest. The texts, furthermore, make proposals of change based on the duty to care for and save water heritage, due to its importance for life (vital-water), for citizens (citizen-water) and for economic development

(economy-water). In addition, they suggest the reduction in the demand for water, a resource conceived as non-renewable due to its over-exploitation. Attention is paid, to a lesser extent, to pollution and citizen participation in water care and management, without losing sight of the fact that over half of the reflections employ binding plural language.

## 5 Discussion and conclusion

In this work it has been possible to verify that the implementation of the *Únete a la Nueva Cultura del Agua* teaching proposal, designed ex-profeso in order to mobilise cultural conceptions associated with water of students aged 14–15 has, to a large extent, achieved its objectives. It has demonstrated significant successes in favouring a transition in the perception of water, connecting it to eating habits and consumer goods, as well as improving the understanding of the urban water cycle among secondary school students. However, there are still areas for improvement: some students still maintain the perception of natural water scarcity without recognising the role of human



ya que conocemos cada etapa del agua, de donde proviene y cuales son los procedimientos para que lleguen a nuestras casas, tenemos que aprender a cuidar más este recurso y no sobreexplotarlo, no botar basuras en las alcantarillas para impedir el flujo del agua, gracias a estas lecciones nos podemos plantear muchas cuidados del agua para un mejor futuro para el mundo en general.

FIGURE 8

Reflection made by a student at the end of the teaching proposal related to learning addressed in other spaces different to Task 10. Now we know each stage of water, where it comes from and what procedures are involved in bringing it to our homes we must learn to look after this resource more and not over exploit it, not throw rubbish in sewers which stops water flow, thanks to these lessons we can propose many ways of looking after water for a better future for the world in general.

behaviour in this problem, and justify the construction of infrastructures despite being aware of their environmental impact.

Specifically, its direct benefits have been:

To favour the transition from a vision of water restricted to the resource itself to another more global and delocalised perspective where water is associated with consumer goods and eating habits. In fact, block 4 of the pretest-posttest questionnaire, which is the one that explores these issues, benefited the most from the teaching proposal. Furthermore, over half of the saving measures put forward by the students at the end of the teaching proposal were related to indirect consumption, something which, prior to its implementation, was completely unthinkable, as already discovered by [Benninghaus et al. \(2018\)](#) and [McCarroll and Hamann \(2020\)](#).

Moreover, although to a lesser extent, there was progress in terms of understanding the relationships of human behaviour with water, indicated by block 3. Water in nature is renewable, thanks to the natural cycle that characterises it. Nevertheless, anthropic actions over the last century are causing it to function as a non-renewable resource ([Naciones Unidas, 2021](#)). In the teaching proposal, the students acquired a greater knowledge of the urban water cycle, overcoming a number of preconceptions also detected in prior studies ([Hernández, 2014](#); [Castelltor, 2015](#); [Liefänder et al., 2016](#); [Pozo-Muñoz et al., 2023](#)).

Following the end of the teaching proposal, however, a considerable proportion of the students:

Continue to think that there are territories with chronic water scarcity, without realising that in many cases such scarcity is due to anthropic actions and not to natural water imbalance. The results associated with block 1 of the questionnaire indicate it thus.

Finally, as it also derives from block 3, they also continue to justify the construction of installations destined towards obtaining greater quantities of water for consumption, despite being aware of their environmental impact. Everything appears to point to environmental damage being justified when it involves covering water supply needs.

In general, while progress has been made in understanding various aspects related to water, there are still areas with a persistence of misconceptions or lack of clarity on sustainable and effective solutions to water management. These areas identified as weaknesses represent opportunities to improve the teaching proposal and strengthen students' understanding of the importance and proper management of water.

A highly significant result of this work is that the aforementioned strengths and weaknesses of teaching proposal largely correspond to the contents of the tasks that were scored highest and lowest, respectively, by the students. Thus, the strengths were worked on in tasks 8 and 6, which involved the different types of water circulating in the aqueduct and sewer system of Bogotá. Among the weaknesses,

task 1 was aimed at studying water scarcity, but did not achieve all of its objectives, which may be due to a design with room for improvement or the fact that it was the first task in the learning sequence. These associations between knowledge and perceptions have also been shown in other studies, which corroborate that learning improves when positive emotions are evoked ([Harlen, 2013](#); [Jiménez-Liso et al., 2020](#); [Marcos-Merino et al., 2021](#)).

We believe that an important proposal for improvement could be the inclusion of a task that demonstrated the connections between natural water-related catastrophes (droughts and floods) and anthropic actions such as deforestation. This task could help students to overcome one of the weaknesses identified, making them more aware of the leading role played by humans in the current scarcity of water in many territories that in times past had an abundance.

Something worth drawing attention to is the high scores given by students in task 8, in which they took part in water analysis practicals. On this point we coincide with experiences such as those of [Acosta et al. \(2019\)](#), [Pallant et al. \(2020\)](#), [Peckenhams et al. \(2012\)](#) and [Raviv et al. \(2019\)](#), among others, which show the preference of students towards practical classes.

To conclude, it is convenient to highlight that the sample involved in this study is evidently a limitation on generalising the results. To this end, we are at this time proceeding to make improvements, in accordance with the weaknesses found, in order to replicate it in other contexts.

Sustainability has to be a fundamental part of the educational strategy ([LOMLOE, 2020](#); [Wolff et al., 2022](#)). The sustainability plan must emanate from the school to create commitment, credibility and clarity in a transverse way throughout the entire educational community. Teachers are positioned to act as essential managers in the construction of knowledge, and to consolidate alliances between schools and society. This teaching proposal helps students to transition towards the sustainability of water resources and, in summary, towards the building of a better world.

## Data availability statement

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

## Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements.

Written informed consent was obtained from the minor(s)' legal guardians/next of kin for participation in the study and for the publication of any potentially identifiable images or data included in this article.

## Author contributions

FC-V: Investigation, Writing – original draft, Writing – review & editing. AR-S: Investigation, Writing – original draft, Writing – review & editing. AB: Investigation, Writing – original draft, Writing – review & 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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