Available online at www.ijournalse.org

Emerging Science Journal

(ISSN: 2610-9182)

Vol. 9, Special Issue, 2025

"Emerging Trends, Challenges, and Innovative Practices in Education"

Cognitive and Affective Analysis in Water Education and Literacy Through Educational Robotics in Elementary School

Alejandro De la Hoz Serrano [1*], Lina Viviana Melo Niño [1], Joào Piedade [2], Florentina Cañada Cañada [1], Javier Cubero Juánez [1]

[1] *Department of Experimental Science and Mathematics Teaching Area, University of Extremadura, 06006 Badajoz, Spain.*

[2] *UIDEF, Instituto de Educação, Universidade de Lisboa, 1649-013 Lisbon, Portugal.*

Abstract

The aim of this study was to examine the impact of Educational Robotics on the cognitive and affective development of primary school students in the context of water education and literacy, with a specific focus on learning the water cycle and healthy hydration habits. A quasi-experimental design with a mixed-methods approach was adopted, involving a sample of 158 students (83 girls and 75 boys). The educational intervention consisted of 12 sessions incorporating interactive activities supported by robotics, and data were collected through pre- and post-intervention questionnaires. The findings revealed significant improvements in scientific knowledge, with students reaching an *Excellent* level in understanding the water cycle and a *Sufficient* level in hydration-related content. From an affective perspective, positive emotions such as *Joy* and *Enjoyment* (81.82%) were predominant, especially in relation to methodological and content aspects, whereas negative emotions were primarily linked to challenges in teamwork and oral communication. The novelty of this study lies in highlighting the value of Educational Robotics not merely as a motivational tool but as a meaningful technological support for learning scientific content. These results emphasize the importance of further research into Educational Robotics potential and the need to address affective barriers to optimize learning outcomes.

Keywords:

Science Education;
Educational Robotics;
Water Education;
Elementary School;
Emotions.

Article History:

Received:	17	February	2025
Revised:	15	October	2025
Accepted:	11	November	2025
Published:	18	January	2026

1- Introduction

Contemporary education faces the growing challenge of preparing students not only to acquire disciplinary knowledge but also to address the complexity of current societal, environmental, and health-related issues [1, 2]. Within this context, water education and literacy have become increasingly relevant topics, given the essential role of water in sustainable development, human health, and environmental stewardship [3]. Despite this relevance, various studies report widespread misconceptions and fragmented understanding among students regarding key scientific concepts such as the water cycle, water systems, and water's role in the human body [3–5]. Additionally, inadequate hydration habits among children reveal a gap in public health education during the early stages of schooling [6-8]. Furthermore, the need for comprehensive learning of these contents is increased, according to the Sustainable Development Goals (SDGs) that are intended to be attained, in which the water is an indispensable and priority resource [9], as well as the new One Health strategy to support the public health needs of the community [10].

Addressing these deficits requires pedagogical approaches that move beyond traditional methods and incorporate digital tools capable of promoting inquiry, motivation, and deep conceptual understanding [11]. Among the most

* **CONTACT**: alexdlhoz@unex.es

DOI: http://dx.doi.org/10.28991/ESJ-2025-SIED1-020

promising digital resources, Educational Robotics (ER) has gained increasing attention due to its capacity to integrate STEM content, develop 21st-century skills, and enhance cognitive and affective learning outcomes [12-18]. Among the most expanding resources, especially in the primary education stage, Educational Robotics (ER) is postulated as one of the tools that have received the highest focus in research in recent years. However, research focused specifically on ER's role in water-related scientific learning remains scarce, and there is a lack of evidence linking robotics-based instruction to improvements in students' conceptual understanding of hydration or environmental science [19-21].

In parallel, the role of emotions in science education has gained recognition, particularly for its impact on students' learning processes, academic decisions, and attitudes toward science [22-24]. While several studies have explored motivational aspects and attitudes, fewer have examined the specific emotional responses elicited during learning activities that involve science content and digital tools, especially in primary education [25-28]. Given that negative emotions can act as barriers to learning, while positive ones such as joy or curiosity can enhance engagement and retention, incorporating an affective dimension into science instruction is essential [29-31].

1-1- Water Education and Literacy

Water education and literacy are essential components of compulsory education due to the critical role water plays in human existence Issues such as water access and quality remain among the most pressing challenges of the 21st century [5]. Research indicates that water education fosters students' critical understanding, attitudes, and behaviors regarding water management and conservation [32]. However, despite its centrality in science curricula, persistent misconceptions about key hydrological processes continue to be reported. Studies highlight scientifically inadequate ideas about water systems, particularly regarding the water cycle, groundwater dynamics, and human-water interactions [33–36]. Given these challenges, a multidisciplinary educational approach is needed to improve students' scientific knowledge and foster a holistic perspective on water-related issues [3, 37].

At the primary education level, the water cycle is a fundamental topic that supports a broad range of scientific knowledge related to water systems [38]. However, research reveals persistent preconceptions among students, particularly concerning groundwater, the interaction between living organisms and the water cycle, cloud formation, and condensation [39–41]. These misunderstandings are often linked to pedagogical methods that emphasize memorization rather than conceptual understanding [38]. Furthermore, studies such as that of Romine [42] underscore the importance of affective factors in science education, highlighting that students' emotional engagement plays a significant role in their learning process.

Beyond environmental aspects, water education also intersects with health-related topics. Many studies have revealed findings not just about students' unhealthy habits but also their lack of scientific knowledge [6-8]. Water, as the main component of the human body, is essential for all vital functions and is officially recognized as a critical nutrient by the European Food Safety Authority [43]. Consequently, the implementation of educational interventions aimed at promoting healthy hydration habits in young populations should be a primary public health concern [44]. Despite this, a paucity of scientific literature focusing exclusively on hydration exists, and most of this literature has focused on the hospital setting. Previous studies [45, 46] illustrate that appropriate population-based interventions can improve scientific knowledge on hydration.

Recent research has also emphasized the concept of water literacy as an integration of water-related knowledge, attitudes, and behaviors [3, 47]. Water literacy is essential to scientific literacy, encompassing earth science and environmental literacy [33]. In this context, several studies are addressing the importance of health literacy in bio-health learning [48, 49]. A recent review by Imaduddin and Eilks [3] examined the state of water education and literacy in formal education, identifying significant limitations in existing teaching practices. Their findings suggest that water education is often fragmented across different curricular areas. Through factor analysis, they identified three key research clusters: Drinking Water, Knowledge and Environmental Education, and Water Systems, suggesting that future research should aim to integrate these topics to provide a more holistic understanding of water-related issues. Therefore, future research could focus on the integration of topics from different clusters, allowing for a holistic approach to water-related learning. In addition, it is important to consider the concept of literacy [50] as a person's ability to seek, understand and use information, and as a consequence of the digitalized society, digital literacy plays a crucial factor in the acquisition of knowledge [51]. For this reason, water literacy must also include people's ability to search for, understand and use water-related information, including information obtained through technological means. This concern led to the research lines related to people's competence to search for, evaluate and use the information that people consult on the Internet, as it has been shown that students have difficulties searching for and discerning the quality of information [52]. Addressing this gap requires the development of educational strategies that enhance students' competence in evaluating and using digital resources for water-related learning.

1-2- Educational Robotics in Science Learning Outcomes

With the rapid development of science, mathematics and informatics [53, 54], Educational Robotics (ER) has emerged as a powerful tool to support student learning through hands-on, integrated experiences in various contexts to improve the quality of teaching and learning. ER encourages the development of computational thinking, logical reasoning, problem-solving, and collaborative learning [15–18], aligning with the Next Generation Science Standards and the Framework for K-12 Science Education and 21st-century educational goals, reinforce the value of engaging students in understanding the interdisciplinary and interconnected nature of science, mathematics and engineering practices [34]. In this context, few studies [19, 53, 55-57] report that ER supports students' learning of concepts in the fields of science, mathematics and CT.

A recent review by Kyriazopoulos et al. [58] extends previous reviews by focusing on research in primary education. Although the results show that ER promotes cognitive and affective outcomes in STEM disciplines, mixed results were found in terms of the impact of robotics on attitudes toward and learning of science. Findings reported by Sáez-López et al. [59], who tested 93 6th-grade students using mBot and Scratch programming, were statistically significant for improved understanding of mathematical and programming concepts but not for science concepts. Cakir & Guven [60], to teach the concept of pulse in the 6th-grade science curriculum, developed an Arduino-supported robotics and coding activity based on the 5E learning model.

Regarding water-related content, research on the effectiveness of robotics-based interventions remains scarce. The study by Sánchez et al. [20] shows that early childhood education students learn successfully using ground-based educational robots. There is already evidence of the benefits of introducing marine robotics into elementary classrooms for science and mathematics education [19, 61]. The Hydrobots project, using robotics to introduce students to STEM disciplines implementing the Engineering Design Process (EDP), was presented by Bampasidis et al. [62]. Liu et al. [63] used underwater robotics (UR) to introduce students into marine engineering, environmental science, and sustainability. UR is an interdisciplinary technology integrating underwater communication, engineering, marine science, computer science, and robotics. Costa et al. [64] also developed a bio-inspired educational tool for the marine environment. With respect to healthy hydration content, the studies by Marcos & García-Peñalvo [21] and De la Hoz et al. [65] showed the adaptation of ER materials in students of different educational stages that allow the learning of biosanitary content. To address this gap, future research should focus on integrating digital tools and constructivist methodologies that enhance students' scientific understanding of water-related topics. Expanding the scope of ER in water education could significantly contribute to improving scientific literacy and fostering interdisciplinary learning.

1-3- Emotions in Science Education

Affective factors—such as emotions, attitudes, and motivation—play a crucial role in shaping students' engagement and performance in science education [22, 23, 29, 30]. However, an increasing disconnect between society and STEM disciplines has been observed, largely due to students' negative perceptions of these fields, which in turn leads to a decline in the pursuit of scientific and technical careers [29, 30]. Over the past two decades, the impact that the affective domain can represent in the process of science teaching and learning and the consequences have been addressed. Studies prove that components such as attitudes and emotions strongly influence science learning [22, 23]. Likewise, studies from the field of Neuroscience and Neuroeducation highlight that emotions are a strong factor in the connections of the brain to perform cognitive and mental functions that enhance learning [24]. Currently, it is considered that the cognitive configures the affective and the affective the cognitive, and it is assumed that emotion has a psychobiological part [24, 66] but it is also a social construction.

Research mainly focused on attitudes towards science learning, with emotions occupying a secondary position. Currently, numerous studies focus on the affective domain of students at different educational stages [25, 26]. The results demonstrate that students in Primary Education present more positive attitudes and emotions than students in higher educational stages [27]. Differences according to the content studied, such as living beings, socio-scientific issues or human beings and health, have also been observed [23, 28]. One major contributor to students' negative emotions towards science is the lack of engaging methodologies that foster curiosity and interest [27]. Science education has generally focused on the learning of theoretical content through traditional methodologies and resources, such as textbooks, which affect the consolidation of previous ideas [30].

In response to these challenges, Bravo et al. [31] highlights the urgent need for interventions that stimulate emotions through activities designed to evoke curiosity, motivation, and surprise. In line with this, Yllana-Prieto et al. [30] suggested that active methodologies can enhance academic performance, critical thinking, and positive emotions, particularly in science education. Educational Robotics (ER) has been identified as a promising tool for fostering positive attitudes toward science and mathematics [53, 54, 67, 68]. While previous research has explored motivation and self-efficacy in ER-based learning, the emotional responses elicited by students during these experiences remain underexplored. A review of the literature underscores the need for further investigation into students' emotions during the learning process of scientific and mathematical concepts [28]. Therefore, it is crucial to analyze the role of emotions in science education, particularly when using digital tools such as ER.

The present study aims to examine the effects of an educational intervention involving Educational Robotics on primary students' learning about the water cycle and hydration. It focuses on two key dimensions: cognitive and affective outcomes. By addressing both domains, the study contributes to filling key gaps in the literature related to water education and literacy, ER integration in science, and the affective dimension of learning. The research objectives are specified specifically below, followed by the methodology used, the results found, the conclusions obtained, and the limitations of the study.

1-4- Objective and Research Questions

The present study aims to analyze the learning outcomes of water education and literacy using Educational Robotics in elementary school students. The specific research questions of the study are as follows:

- RQ1: What impact does the use of Educational Robotics present in the learning of scientific knowledge related to the water cycle in elementary school students?
- RQ2: What impact does the use of Educational Robotics present in the learning of scientific knowledge related to the habit of healthy hydration in elementary school students?
- RQ3: What impact does Educational Robotics present on the emotions of elementary school students?

2- Research Methodology

2-1-Study DESIGN and PARTICIPANTS

The study adopted a quasi-experimental design with a mixed approach (QUAN-QUAL) through the use of a descriptive and inferential quantitative method and a qualitative approach with the use of a system of categories [69]. The design and implementation of the didactic proposal were carried out through a convenience sample with a total of 158 students (83 females and 75 males) belonging to the 5th-grade of Primary Education, where 88 students (45 females and 43 males) belonged to the experimental group, through the use of Educational Robotics, and 70 students (38 females and 32 males) belonged to the control group without Educational Robotics. The selection of the sample was carried out under two inclusion criteria, which consisted of students belonging to the 5th grade of primary education and that they had no previous experience with ER. The mean age of the students was 11.56 (±0.55). This study was conducted in accordance with the principles of the Declaration of Helsinki (WMA) [70] and was approved by the Human Research Ethics Committee of the University of Extremadura. Written informed consent was obtained from all participants. Questionnaires were anonymized, and participants could opt out of the study whenever they felt uncomfortable.

The implementation flowchart of this research can be seen in Figure 1. Sun & Liu [71] indicated that learning styles must also be considered when introducing Educational Robotics into the educational course. A collaborative group approach was considered the most appropriate for robotics projects. Therefore, the students were randomly divided into groups of 3-4 people each. However, the gender balance was considered to ensure that each group consisted of male and female students.

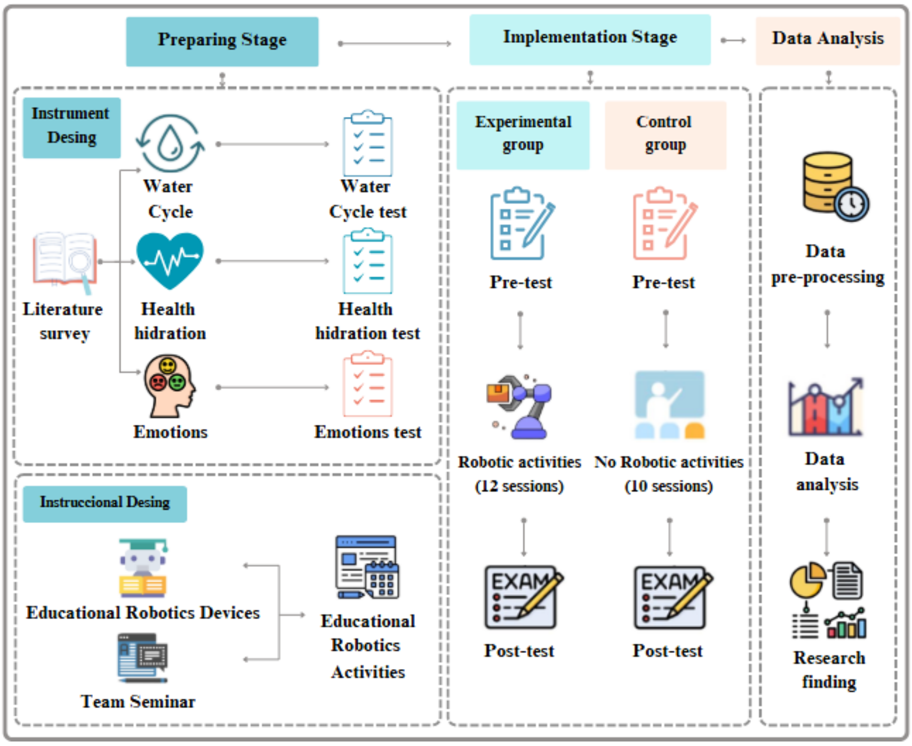

Figure 1. Flowchart of this research

2-2-Intervention

The educational intervention was performed with a total of 12 activity sessions in the experimental group and 10 sessions in the control group, of 50 minutes each, with one session before and one session after to complete the questionnaires. This intervention was conducted from February to May 2024, to promote water education and literacy. All sessions were designed and conducted by the research group, in order to reduce the influence of external variables, as in this case, the teacher's knowledge of each classroom. Specifically, concepts that present greater preconceptions or learning difficulties about the water cycle were assessed [39, 41, 72-75] and habit of healthy hydration [8, 43, 76-79]. Likewise, Figure 2 shows the Water Literacy Framework adapted for the current study.

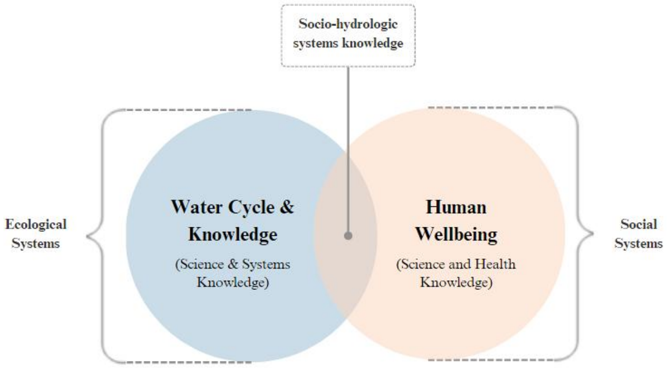

Figure 2. Water Education and Literacy Framework adapted for the current study

According to the literature survey, different educational robotics kits were selected, such as the Micro:bit® and Cutebot® devices, as well as the new Lego Spike Essential® and Prime® kits. Table 1 shows the sessions developed for each content and a description of each activity in the experimental group. First, the initial two sessions are focused on the knowledge of the characteristics of robotic parts and their first block programming, so the scientific content was not addressed in these sessions. The first activities for both the habit of healthy hydration content (session 3) and the water cycle (session 8) were focused on the use of robotic boards (Appendix I). In addition, in sessions 4 and 5, students continue using the board, although the programming complexity is increased with sensors, increasing the challenge to be achieved. As for session 8, as a consequence of the knowledge of the previous sessions, it begins directly with the use of sensors. These robotic boards are divided into different cells, corresponding to different contents that encompass the general content. Thus, students must respond to different questions or challenges proposed by moving the robot to the correct cell.

Table 1. Description and relation of the Educational Robotics activities performed for each scientific content

Session	Content knowledge	Activity	Activity Description
Pre-session	**WC; HHH**		**Pre-test questionnaire**
1		Micro:bit®; Cutebot®	Initiation to the Micro:bit® and Cutebot® devices, their characteristics and functionality
2		Micro:bit®; Cutebot® programming	Introduction to block programming
3	HHH	Robotic board	Board of contents where students must program the Micro:bit® and Cutebot® to move to one or more of the cells on the board.
4-5	HHH	Basic programming of distance and sigueline sensors	Students must employ the distance sensors in order to stop the robot when it approaches an obstacle, and the line sensor to automatically follow a specific path marked on a template. Both sensors are employed with the use of boards similar to the previous sessions.
6-7	HHH	Remote control	Control the Cutebot robot by using two Micro:bit® cards, one in the Cutebot® and one external, as a remote control.
8	WC	Robotic board and color sensor	Students must program a Lego Spike® model to move on a robotic board with content about the Water Cycle. In this activity, students use the color sensor to perform different simultaneous obstacles, enabling each color to program a different movement to perform the correct route.
9	WC	Lego Essential® y Prime®	Assembling different Lego robotic constructions (Essential® and Prime®). Each group of students must perform a different challenge, corresponding to different contents of the water cycle.
10-11	WC	Programming	Programming of the assemblies, according to the challenge of each group.
12	WC	Programming and exposure	Presentation of work to colleagues
Post-session	**WC; HHH**		**Post-test questionnaire**

WC=Water Cycle; HHH=Habit of Health Hydration

In sessions 6 and 7, students learn how to use the software radio-related programming block (Figure 3), connecting Micro:bit® cards. The objective is to move the robot, allowing it to collect different numbered tokens corresponding to different concepts of the habit of healthy hydration. Each group works with different concepts, so they have to collect different tokens. In addition, they can stop the robot by means of previously used sensors.

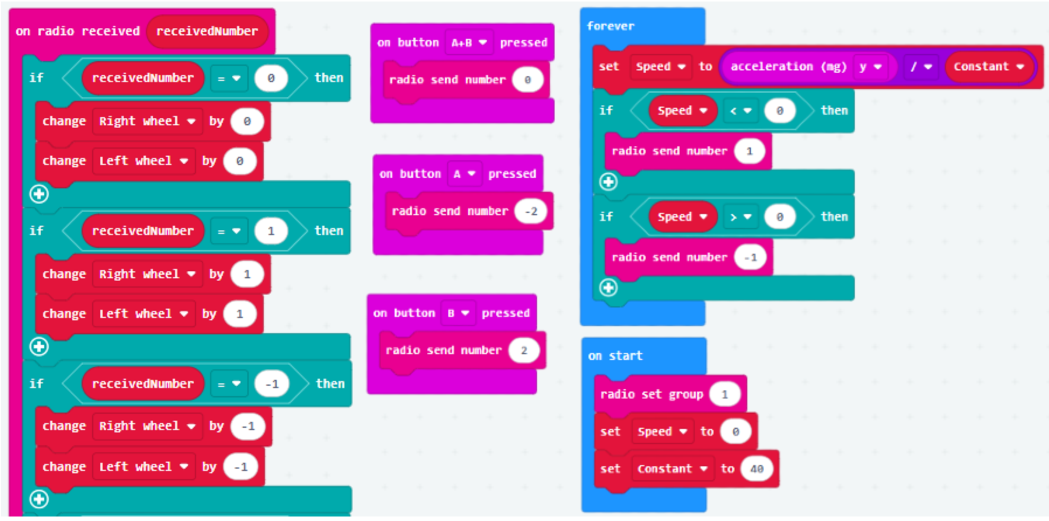

Figure 3. Example of Micro:bit® programming

In sessions 9 to 12, students were required to assemble and program constructions with the Lego Spike Essential® or Prime®. Each group of students must perform a different challenge, which will be presented at the end of the sessions to the peers in the classroom to encourage peer learning. The following challenges were proposed for each group: a) Assembly and programming of a construction that allows functioning as an indicator of different amounts of water waste in actions of living beings; b) Assembly and programming of a construction that allows performing a movement that represents the displacement of water during evaporation and precipitation; c) Assembly and programming of construction to be used in a manual silhouette of a well, allowing to perform the output of water automatically; d) Assembly and programming of construction that can explain the phases of the process of cloud formation in an orderly manner. Figure 4 shows examples of the activities carried out by the students throughout the sessions.

Figure 4. Examples of the activities carried out by the students throughout the sessions

In the same way, all students were guided and instructed in some content by means of infographics, always from the same sources of scientific foundation. It should be made clear that all the websites related to health knowledge must have the Digital Health Quality Seal: Health On Net Foundation (HON), which ensures their scientific and biosanitary rigour, providing them with resources to improve their Digital Health Literacy [65]. Additionally, a custom-designed educational website, published on the *Procomún* platform (https://procomun.intef.es/ode/view/es_2023060712_9123916), was presented as a tool for guiding students in Digital Health Literacy [80].

The activities in the control group were conducted using the traditional method, which presented the contents in an explicative style. Likewise, the students carried out activities involving challenges and a final exposure; in this case, by making manipulative activities such as information sheets, posters or murals.

2-3- Data Collection and Analysis

In order to determine the level of scientific knowledge, two specific questionnaires were used for each content (water cycle and habit of healthy hydration), with a total of 14 questions. Both questionnaires were completed by the students both before and after the intervention, in order to verify the background of both groups, and the level achieved after the use of ER. The water cycle questionnaire (Appendix II) consisted of a total of 8 multiple-choice questions with 4 options and only one correct answer. The pre- and post-tests were devised based on the conceptual framework of water, and misconceptions about the water cycle were documented, as previous studies have done [4]. For the validation of the questionnaire a Cronbach's alpha was applied, which obtained a final value of 0.71, which is an acceptable or moderate value [81].

On the other hand, the habit of healthy hydration questionnaire (Appendix III) consists of a total of 6 open-ended questions. The questionnaire has been adapted from previous studies [82] that have analysed the scientific knowledge of a similar sample. Likewise, the questionnaire has been constructed based on the most relevant contents that the students should know to acquire adequate learning of the habit of healthy hydration contents, according to previous studies and recommendations of international entities [43, 76, 77]. To evaluate the students' answers and their level of scientific knowledge, an evaluation system and a scale of categories from previous studies have been implemented [65]. The evaluation system is based on 3 evaluation categories: correct, semi-correct and incorrect, with scores of 1 point, 0.5 points and 0 points, respectively, in order to determine the average result from 0 to 4 for the four open questions. The scale of assessment is based on the percentage of correct answers assigned to one of the 4 corresponding categories. For the validation of the questionnaire, Cronbach's alpha was applied, which obtained a final value of 0.71.

To analyse the students' emotions, a questionnaire was used at the end of the intervention based on previous studies [83]. The questionnaire consists of a total of 6 emotions, with the aim of finding if the students have felt or not each emotion, in addition to the following question: In which moment and why did you feel this emotion? For the creation of the category system, the Grounded Theory technique was used, which consists of the formation of the category system from the sources of information received [84].

For data analysis, the Microsoft Office Excel 365® program was used for descriptive analysis using averages (X), frequencies (F), percentages (%) and standard deviations (SD). Following the conclusion of the Kolmogorov-Smirnov test ($p<0.05$), which indicated that the data did not follow a normal distribution, nonparametric inferential statistical tests were applied. The Mann-Whitney test was used to determine if there were significant differences between independent samples of students. As for the specific tests applied, McNemar's statistical test was used to analyse the evolution of the correct and incorrect answers to each item in the questionnaire on the water cycle. The Wilcoxon test was used to analyse the evolution of the habit of healthy hydration questionnaire, as well as the total averages of both questionnaires. To perform these tests, the 'R-Commander' interface of "R" was used to perform the different statistical tests [85]. For the qualitative analysis of students' emotions, the WebQDA software [86] was used.

3- Results

This section describes the results of the studies. First, the results related to the cognitive domain of the students are presented, where the results of the questionnaires on the scientific knowledge of the water cycle and the habit of healthy hydration are described. Subsequently, the results obtained in relation to the affective domain through the students' emotions are described.

Table 2 shows the results of the scientific knowledge related to the water cycle before and after the intervention based on Educational Robotics. The averages (X), standard deviations (SD), the results of the statistical tests for each item (McNemar test) and the total average of the questionnaire (Wilcoxon test) are presented. Likewise, the connection is established for each question and the total average with the level of scientific knowledge (LSK) of the categorization used in the study.

As can be observed, there is a significant improvement in most of the items, as well as in the total average, both in the control and experimental groups. With respect to the control group, statistically significant differences ($p<0.05$) were observed in items 1, 5, 7 and 8, as well as in the total average of the questionnaire. As for the post-test, these differences were observed in all the items of the questionnaire. In addition, some results are observed with signs of significance ($p \approx 0.05$). In this case, they can be appreciated in items 2 and 6 of the pre-test. Regarding the Level of Scientific Knowledge, it is observed that most of the pre-test items are positioned between the *Inadequate* and *Problematic* levels, except for item 2, which is a *Sufficient* level in both groups. Regarding the post-intervention results, the items are positioned between the *Sufficient* and *Excellent* levels, except items 3 and 4, with an Inadequate level of the control group and

Problematic level of the experimental group. Figure 5 presents the percentages of success for each item and the total average, according to the group, both before and after the intervention. In addition, the limit is established with the percentage that limits the *Excellent* level of scientific knowledge.

Table 2. Descriptive and inferential results on the knowledge of the water cycle before and after the intervention

Item	Group	Pre-test		LSK	Pos-test		LSK	McNemar test		
		X	SD		X	SD		X^2	*p*	
1	C	0.23	0.43	I	0.63	0.49	S	10.90	<0.01*	
	E	0.29	0.36	P	0.86	0.32	E	19.20	<0.01*	
2	C	0.54	0.51	S	0.74	0.44	S	3.77	0.05	
	E	0.51	0.51	S	0.86	0.36	E	9.00	0.00*	
3	C	0.06	0.24	I	0.11	0.32	I	0.67	0.41	
	E	0.06	0.24	I	0.43	0.50	P	13.00	<0.01*	
4	C	0.11	0.32	I	0.14	0.36	I	0.20	0.66	
	E	0.11	0.32	I	0.46	0.50	P	12.00	<0.01*	
5	C	0.34	0.48	P	0.80	0.40	E	11.6	<0.01*	
	E	0.31	0.50	P	0.91	0.28	E	21.00	<0.01*	
6	C	0.37	0.49	P	0.60	0.50	S	4.00	0.05	
	E	0.43	0.50	P	0.91	0.28	E	15.2	<0.01*	
7	C	0.20	0.40	I	0.77	0.43	E	16.7	<0.01*	
	E	0.29	0.46	P	0.91	0.28	E	20.20	<0.01*	
8	C	0.26	0.44	P	0.63	0.49	S	9.94	0.00*	
	E	0.29	0.46	P	0.89	0.32	E	21.00	<0.01	
								Wilcoxon test		
								S	*p*	ES
Total	**C**	**2.11**	**0.26**	**P**	**4.43**	**0.26**	**S**	**27.00**	**<0.01***	**0.91**
	E	**2.29**	**1.36**	**P**	**6.26**	**1.36**	**E**	**32.00**	**<0.01***	**0.92**

* Statistically significant differences; C=Control; E=Experimental; I= Inadequate; P= Problematic; S= Sufficient; E= Excellent

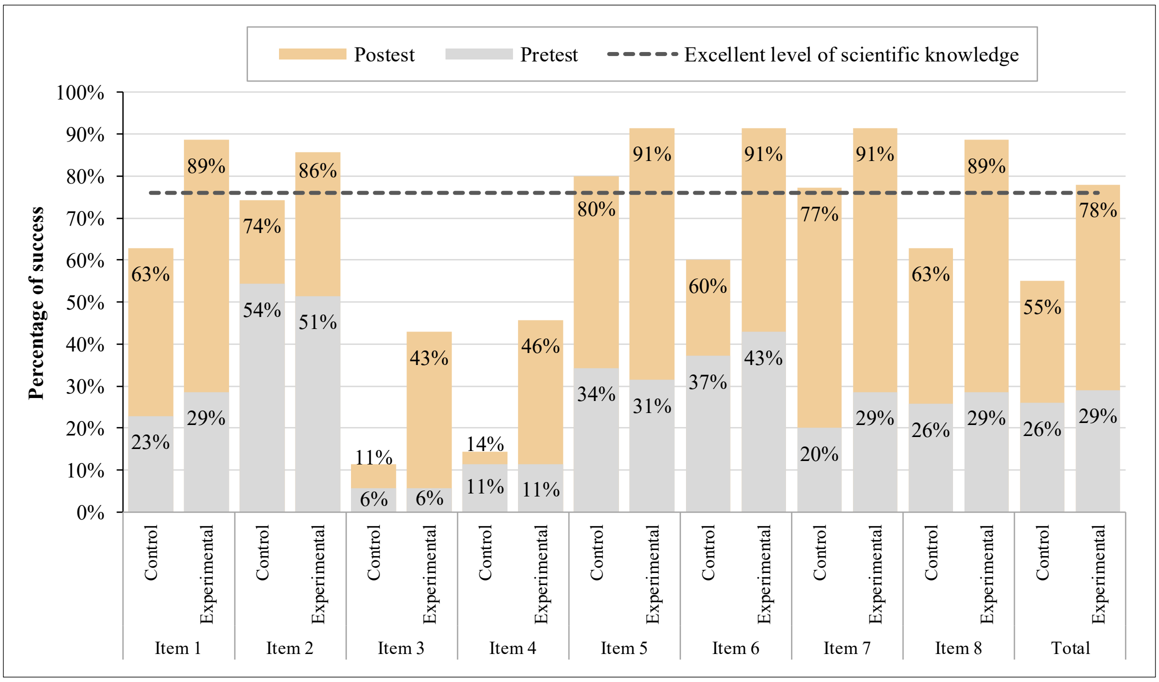

Figure 5. Percentage of correct answers to the Water Cycle Questionnaire

The pretest results reveal that none of the items achieved the *Excellent* level. In contrast, the posttest results show that items 1, 2, 5, 6, 7, 8 and the total average of the experimental group exceeded this limit, while only items 5 and 7 of the control group exceeded it. Regarding the results related to the scientific knowledge of the habit of healthy hydration, Table 3 shows the averages (X), standard deviations (SD) and the results of the statistical tests for each item and for the total average of the questionnaire (Wilcoxon test). Likewise, the connection with the level of scientific knowledge (LSK) is established.

Table 3. Descriptive and inferential results on knowledge of the habit of healthy hydration before and after the intervention

Item	Group	Pre-test		LSK	Pos-test		LSK	Wilcoxon test		
		X	SD		X	SD		S	*p*	ES
1	C	0.16	0.37	I	0.55	0.51	S	17.00	0.00*	0.75
	E	0.27	0.45	P	0.78	0.42	E	24.00	<0.001*	0.83
2	C	0.19	0.40	I	0.45	0.51	P	0.00	0.01*	1.00
	E	0.30	0.46	P	0.51	0.51	S	5.50	0.01*	0.80
3	C	0.03	0.18	I	0.26	0.45	P	0.00	0.01*	1.00
	E	0.08	0.28	P	0.62	0.49	S	0.00	<0.001*	1.00
4	C	0.60	0.35	P	0.73	0.31	S	13.50	0.08	0.59
	E	0.66	0.29	P	0.81	0.25	E	0.00	0.001*	1.00
5	C	0.03	0.18	I	0.03	0.18	I	0.00	NaN	NaN
	E	0.00	0.00	I	0.19	0.40	I	0.00	<0.001*	1.00
6	C	0.11	0.25	I	0.19	0.31	I	15.00	0.18	0.45
	E	0.19	0.29	P	0.53	0.26	P	0.00	<0.001*	1.00
Total	**C**	**1.13**	**0.76**	**I**	**2.21**	**0.86**	**P**	**4.00**	**<0.001***	**0.98**
	E	**1.50**	**1.01**	**I**	**3.43**	**1.43**	**S**	**9.00**	**<0.001***	**0.97**

* Statistically significant differences; C=Control; E=Experimental; I= Inadequate; P= Problematic; S= Sufficient; E= Excellent

As can be observed, there is a significant improvement in most of the items, as well as in the total average, both in the control and experimental groups, except for the items 5 and 6 in the control group. In this case, the results before the intervention show that all the items belong to the categories of the *Inadequate* and *Problematic* levels. In contrast, in the post-test, the 4 levels (*Inadequate, Problematic, Sufficient* and *Excellent*) can be observed. The items 1 and 4 presents an *Excellent* level; items 2 and 3 presents a *Sufficient* level; item 6 presents a *Problematic* level; finally, item 5 presents an *Inadequate* level.

Figure 6 illustrates the percentages of success for each item and the total average as a function of the group, both before and after the intervention. In addition, the limit is established with the percentage that limits the *Sufficient* level of scientific knowledge.

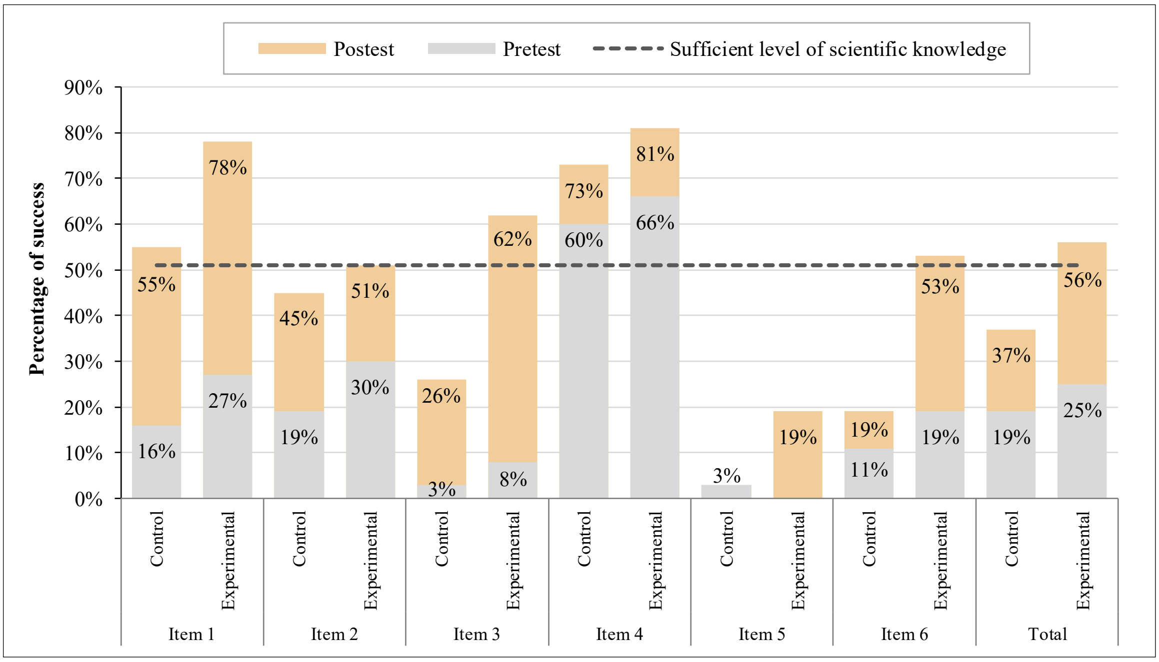

Figure 6. Percentage of correct answers to the Health Hydration Questionnaire

The results indicate that just item 4 is above the limit before the intervention. Subsequently, items 1, 3, 4, 6 and the total average of the experimental group exceed the limit. As for the control group, items 1 and 4 are the only ones that manage to reach the *Sufficient* level. Regarding the differences between the control and experimental groups, Table 4 shows the results of the Mann-Whitney U test for each of the items as well as for the total average, in both scientific knowledge.

Table 4. Statistical results of the Mann-Whitney U test between the control and experimental groups

Water Cycle					Habit of healthy hydration				
Item	Test	U-Mann Whitney test			Item	Test	U-Mann Whitney test		
		S	*p*	ES			S	*p*	ES
1	Pretest	578	0.60	0.06	1	Pretest	511	0.29	0.11
	Postest	455	0.01*	0.26		Postest	439	0.04*	0.24
2	Pretest	595	0.82	0.03	2	Pretest	514	0.33	0.10
	Postest	543	0.24	0.22		Postest	538	0.62	0.06
3	Pretest	613	1.00	0.00	3	Pretest	546	0.41	0.05
	Postest	420	0.00*	0.31		Postest	365	0.00*	0.36
4	Pretest	613	1.00	0.00	4	Pretest	523	0.49	0.09
	Postest	420	0.00*	0.31		Postest	499	0.29	0.13
5	Pretest	595	0.81	0.03	5	Pretest	555	0.29	0.03
	Postest	543	0.18	0.11		Postest	484	0.04*	0.16
6	Pretest	578	0.63	0.06	6	Pretest	499	0.23	0.13
	Postest	420	0.00*	0.31		Postest	250	<0.001*	0.56
7	Pretest	560	0.41	0.09					
	Postest	525	0.11	0.14					
8	Pretest	595	0.80	0.03					
	Postest	455	0.01*	0.26					
Total	**Pretest**	**570**	**0.61**	**0.07**	**Total**	**Pretest**	**470**	**0.19**	**0.18**
	Postest	**225**	**<0.001***	**0.62**		**Postest**	**274**	**<0.001***	**0.52**

* Statistically significant differences

As can be noted, statistically significant differences can only be found in the results corresponding to the post-test, in both questionnaires. Regarding the water cycle, statistically significant differences are found in items 1, 3, 4, 6, 8 and the total average. Regarding the habit of healthy hydration, statistically significant differences are observed in items 1, 3, 5, 6 and in the total average.

Below are the results related to the emotions felt by the students during the learning process with the ER resource. Figure 7 presents the frequencies of each of the emotions based on whether or not the students felt each of the emotions. The results show that the emotions most felt are *joy* and *fun* (72 students each), followed by *surprise* (50 students), *nervousness* (35 students), *anger* (26 students), and finally, *boredom* (20 students). To clarify, 8 students did not respond to any of the emotions, in addition to 2 other students (10 in total) who did not respond to the *Boredom* emotion.

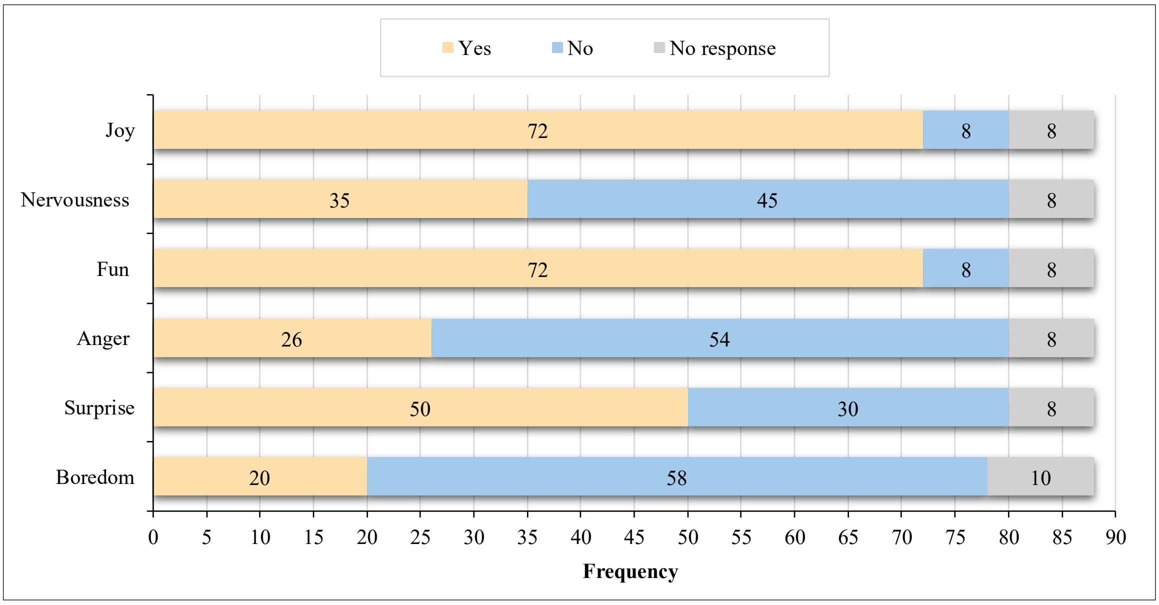

Figure 7. Frequency of response in each emotion

An emergent system of categories has been established through the qualitative analysis of various emotions. Figure 8 presents the results of the qualitative analysis, displaying the different categories identified for each emotion, which explain the underlying reasons for the emotions observed. Additionally, Appendix IV provides the category system, including the frequencies of each category, their relative percentage of the total responses within each dimension, and examples that justify the creation of each category.

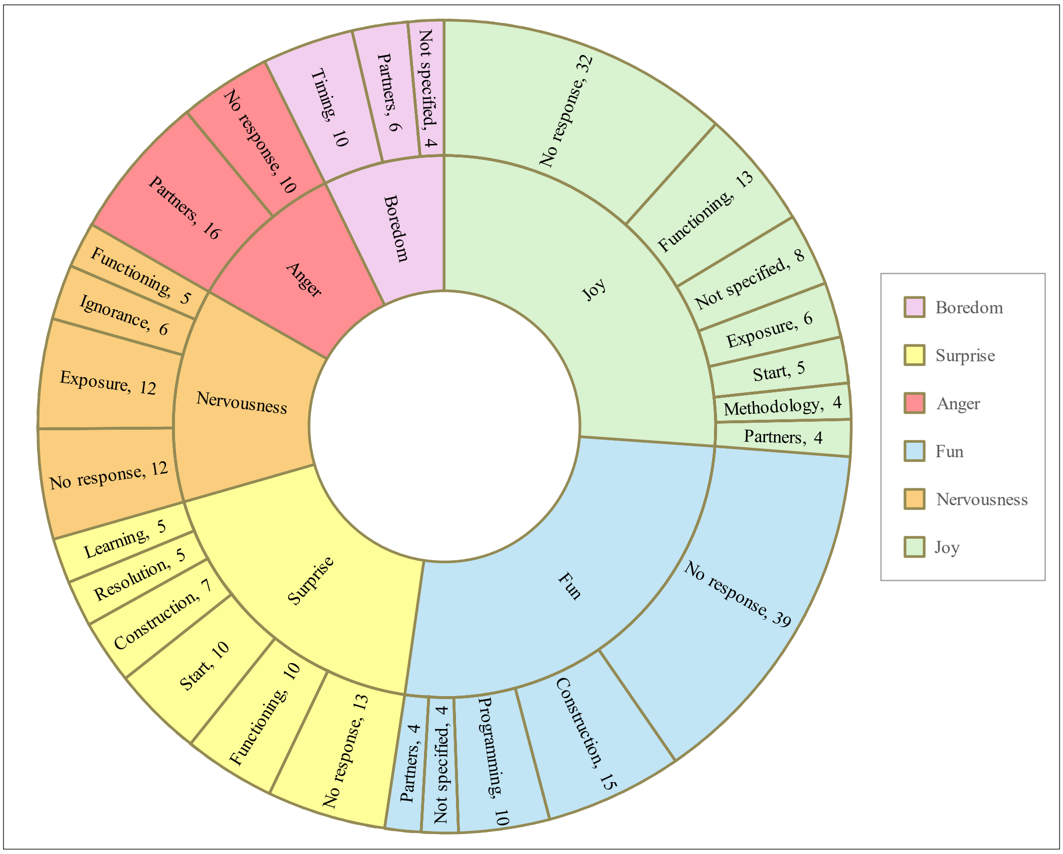

Figure 8. Solar projection graph for each response category

Regarding the emotion *Joy*, almost half of the students (32) did not answer about the causes of this emotion. It can be highlighted that 18.06% of the students have expressed that they have felt this emotion with respect to the functioning of the robot. Examples of this category are the following: "*When the robot did what we wanted*" (student 34). Other reasons for feeling the *Joy* emotion have resulted from the satisfactory presentations of the project (6), from working with peers (4), and from the learning methodology (4). Likewise, 6.94% of the students reflected this emotion at the start of the activity, mainly as a consequence of the novelty of the activity. On the other hand, the *Fun* emotion was more focused on the initial construction of the robots (20.83%). Although more than half (54.17%) of the students did not respond, causes such as teamwork (4) and the programming itself (10) can be found. On the other hand, only 5.56% of the students did not specify. An example of this is the following: '*When the robot functioned thanks to my programming*" (student 17).

Considering the *Surprise* emotion, both the *Start* and *Functioning* categories account for 20% of each student response. In this case, the *Start* category reflects the surprise felt by the students both before starting: "*When I found out I was going to use robots*" (student 11), during the first day: "*The first day, not knowing what we would do*" (student 21), and the first time they programmed the robot: "*When I was able to move the robot the first time*" (student 70). Other causes observed are the construction of different models (7), the learning of content (5) or the ability to solve the problems encountered (5). In this case, 26% of the students did not answer the reasons for the emotion.

Conversely, *Anger* presents only one category (*Partners*), except those who did not specify an answer. In this case, 61.54% of the students who felt this emotion expressed that it was a consequence of teamwork: "*When classmates did not let a girl in the group do something*" (student 49).

Boredom shows that 50% of the students felt this emotion because they had nothing to do for a period of time, either because they were waiting for their partner to finish his part of the work: "*Because I have to wait for my partner to assemble the robot*" (student 9) or when they all had to wait for the rest of the group to do the following activity: "*When we already had the work and we had to wait for the others*" (student 65). The other reason is teamwork (6), while 4 did not specify the causes of the emotion they felt.

Finally, the emotion of *Nervousness* reflected the presentation that the students had to make to the rest of the group to show the project, accounting for 34.29% of the total. Other causes are the *Ignorance* (6): "*At the beginning. I didn't know if I was going to be bored or entertained*" (student 32) and the *Functioning* (5): "*When we had to finish and the program was not going well*" (student 77). Finally, 12 students did not respond.

4- Discussion

In a global environment mediated mainly by science, technology and mathematics, Educational Robotics (ER) is presented as a powerful pedagogical tool that not only allows the development of essential skills such as problem solving, critical thinking and collaborative work - crucial skills for the formation of creative and adaptable citizens - but also fosters positive attitudes towards the fields of science and mathematics [13, 87]. The integration of this active methodology encourages a change in the traditional way of teaching, allowing students to acquire knowledge through practical, hands-on, specific experiences based on the resolution of challenges. In this line, the present study aimed to analyze the impact of the use of ER on the scientific knowledge and emotions of elementary school students, through the development of activities focused on water education and literacy, with content on the water cycle and the habit of healthy hydration.

In response to RQ1: *What impact does the use of Educational Robotics present in learning scientific knowledge related to the water cycle in elementary school students*? The results of the study show that the incorporation of Educational Robotics had a significant and positive impact on the learning of the water cycle.

In the pretest, both the experimental and control groups showed a *Problematic* level of knowledge, with no significant statistical differences between them, which confirms the initial homogeneity of the samples. Specifically, all items, except item 2 (*Sufficient* level), show an Inadequate or *Problematic* level. In this sense, the results coincide with previous studies [39-41] that show those contents of more difficulty in learning and that usually involve strong preconceptions in the students, such as groundwater, the influence of Living Beings, and especially in items 3 and 4, being the lowest averages, belonging to the cloud formation. However, after the intervention, while the control group reaches a *Sufficient* level of scientific knowledge, the experimental group presents an *Excellent* level. As shown in Figure 5, items 1, 2, 5, 6, 7, 8 and the total average of the experimental group reach an *Excellent* level, with only items 5 and 7 of the control group achieving it. This coincides with previous studies [88], where students reached a similar level of scientific knowledge after interventions based on digital literacy and the use of active learning methodologies. Likewise, it is reflected that students present higher assimilation ability on contents related to living beings, since they belong to the items in which both groups reach the *Excellent* level.

After the intervention (Table 2), there are statistically significant differences between pretest and posttest results. The results reflect that, although both groups have shown significant learning after the intervention, the students who have learned through Educational Robotics have more successful results. These results are in line with previous studies which demonstrate improved learning after ER-based interventions on science and mathematics content in water education and literacy [20, 61, 89, 90], as well as on the teaching of various science and mathematics content in elementary school [59, 91-93]. Thus, ER has allowed higher learning of the contents related to the differences between oceanic and continental crust, the understanding of the directionality of the water cycle and groundwater, being these contents of a high scientific value in the understanding of the water cycle [38, 73].

However, there were items that presented major challenges, even after the intervention. Examples are cloud formation and condensation (items 3 and 4), where both groups maintained low levels of achievement. This indicates that these concepts, due to their level of abstraction, continue to be complex for the students, coinciding with previous studies that emphasize this barrier in the teaching of natural sciences in elementary school [39, 41]. Nevertheless, the experimental group showed significant progress, showing a higher level of knowledge (*Problematic*) than the control group (*Inadequate*) in both items. Thus, ER allowed students to visualize and interact with processes that would otherwise be difficult to represent.

With respect to RQ2*: What impact does the use of Educational Robotics present in the learning of scientific knowledge related to the habit of healthy hydration in elementary school students?* The results also indicate a positive effect of the use of robotics, although of a lower scale than in the water cycle. Similarly to the scientific content of the water cycle, the pretest results show that there are no statistically significant differences between the control and experimental groups, but, after the intervention, these differences are statistically significant (Table 4).

Regarding the level of scientific knowledge (Table 3), there is an *Inadequate* level in both groups before the intervention. However, the level after the intervention of the experimental group is *Sufficient*, while the control group presents a *Problematic* level. Although both groups present statistically significant differences between the pretest and posttest results, the differences between groups demonstrate the positive effect of Educational Robotics in learning scientific content. These results coincide with previous studies where their students have experienced improved learning due to interventions based on health literacy [88, 94, 95], through active methodologies and based on digital resources [6-8] and specifically in studies illustrating the impact of Educational Robotics in the teaching of biosanitary contents [21, 65].

It can be noticed (Table 3 and Figure 6) that only item 4 achieved a *Sufficient* level before the intervention in both groups. However, after the intervention, items 1, 3, 4, 6 and the total average of the experimental group reach this level, in contrast to the control group, where only items 1 and 4 achieve it. This indicates that the students demonstrate greater assimilation of scientific content in relation to the daily intake of water they should consume, since item 1 is the only one that coincides in both groups. On the contrary, the most difficult item is still related to the main function of water in the organism, where the control group does not present improvements in the post-test values. In this context, ER has allowed better learning of contents related to the water intake of food, the differences between natural and bottled juices and the benefits of hydration, which are contents of vital importance in Health Education and Promotion [44, 78, 79].

Specifically, item 5, referring to the function of water in the body, was the most complex for the students, even after the intervention. The experimental group, although it improved, only reached a mean of 0.44, while the control group did not exceed 0.28. This difficulty can be explained by the more abstract nature of this content and its minor representation in the traditional school curriculum, as previous research has shown [94, 95]. Likewise, there are very low averages on the hydration contribution of food for the human body (item 3) in both groups. These values coincide with previous studies [94, 95] that demonstrate the existing problem of the low scientific knowledge of students in the initial educational stages about the habit of healthy hydration.

It is remarkable that, when comparing both contents (water cycle and healthy hydration), a higher performance is observed in the first one. This difference may be attributed to multiple factors: (1) the water cycle is a content more frequently addressed in primary education curricula; (2) teachers are more familiar with adapting robotics to natural content than to health content; and (3) the water cycle assessments were based on multiple-choice questions, while the hydration assessments included open-ended questions, which may have had a negative influence on student performance [96].

Regarding RQ3: *What impact does Educational Robotics present on the emotions of elementary school students?* The qualitative results show that the ER generated mainly positive emotions, which is a key finding in the promotion of positive attitudes towards scientific learning thanks to Educational Robotics.

The emotions of *Joy* and *Fun* were the most frequently reported, with a significant number of students (72 for *Joy* and 72 for *Fun*) reported feeling these emotions during the activity with ER. If we attend specifically to the different categories of the qualitative analysis conducted on the causes of each emotion (Appendix IV), some reasons that made the students feel *Joy* can be pointed out. A considerable percentage of students (18.06%) expressed this emotion due to the robot's function. This fact does not refer only to the fact that students are joyful because of the movement of the robot, but to the close relationship that students establish when they work with a tangible robot, in which an action is reflected because the student has programmed it themselves, as can be seen in the following response from a student: "*When the robot worked thanks to my programming*" (student 17). Previous studies [53, 54] have shown that students increase their positive attitude about scientific and mathematical areas through ER activities, just as previous studies have shown that students feel positive emotions during the learning of scientific content thanks to STEM methodologies or digital resources [30].

The *Surprise* emotion also shows a positive effect of the integration of ER in the content learning. Among some reasons observed, we can find the construction of different models (7) or the ability to solve the problems encountered (5). Thus, it is reflected that the use of Educational Robotics allows addressing important aspects such as creativity or problem solving, especially in Challenge-Based Learning methodologies [97]. These results reflect the positive emotional value that ER provides, which allows to approach in a more significant way the learning of scientific contents. Likewise, the students reflect that they have felt this emotion during the learning of content (5), which coincides with the better learning in the students of the experimental group, since the students have had greater involvement in the learning of the content.

It should be highlighted that students refer to the difference in learning methodology, emphasizing that learning content "*is better than using the textbook*" (student 59). In this sense, a clear link is established between the learning of scientific content and methodologies distanced from the use of textbooks, and particularly in the content of the Water Cycle, where studies [38] highlight that textbooks incite a lack of scientific understanding of the processes of this content. In parallel, it is highlighted that students felt Surprise, not only as a consequence of the methodology, the construction of the robot or its functioning, but also of the learning of the content itself: "*Because by using the robot I learned that natural juice had less sugar*" (student 8), which coincides with studies [15, 17] that reflect that the ER motivates students to carry out activities in the areas of science and mathematics, allowing learning in a more playful way.

Regarding *Anger* and *Nervousness*, the main causes do not allude to the ER, but belong to other aspects during the intervention, such as teamwork or project exposure. Under this perspective, there are multiple studies [87, 98] that have demonstrated the use of ER as a means of improving cooperation skills among students and that determine that ER-based activities should be carried out in groups to encourage these skills. Given this, it would be appropriate to continue promoting activities with the same methodology that allows the development of cooperation and group work skills.

As for *Boredom*, students felt this emotion because they were not doing the robotics activities for a certain period of time, either because they were waiting for their partner to finish his part of the work: "*Because I have to wait for my partner to assemble the robot*" (student 40) or when they all had to wait for the rest of the groups to do the next activity: "*When we already had the work and we had to wait for the others*" (student 65). In this sense, similarly to the emotion *Anger*, it reflects a problem in collaboration and teamwork abilities. This may be a consequence of the activities in which each group of students performed a different challenge, so there were challenges that were easier to solve than others.

In view of all the results, Educational Robotics can be considered as an effective tool of teaching scientific and mathematical content. The results demonstrated a significant improvement in scientific knowledge level, notably in those students who have performed activities based on robotics and programming. At the same time, the affective domain results show that ER promotes positive emotions in the science education process that usually corresponds to negative emotions and learning difficulties. For all the above, it is advocated for more studies that analyze ER's cognitive and affective impacts on multiple scientific and mathematical contents.

5- Conclusion

This study highlights the significant educational potential of Educational Robotics (ER) as an active methodology for learning scientific content and promoting positive emotional experiences in elementary education. The results demonstrate a clear cognitive impact: students who participated in the ER-based intervention significantly improved their understanding of both the water cycle and healthy hydration habits. The experimental group reached an *Excellent* Level of Science Knowledge (LSK) in water cycle content and a *Sufficient* level in hydration, outperforming the control group in both areas. While certain abstract concepts, such as cloud formation and the role of water in the human body, remained challenging, ER supported greater conceptual progress even in these cases, aligning with prior research emphasizing the importance of tangible, visual learning tools in science education.

Equally important is the affective impact observed. The emotions most frequently reported were *Joy*, *Fun*, and *Surprise*, which were closely linked to hands-on programming and the robot's functioning—moments when students felt agency over their learning. Notably, emotions such as *Surprise* were also related to content discovery, suggesting that ER not only facilitates learning but enriches the emotional experience of acquiring knowledge. Negative emotions like *Boredom* and *Anger* were mostly associated with organizational issues or teamwork dynamics. These findings reinforce the value of ER in creating engaging, emotionally positive science learning environments, while also underlining the need for thoughtful classroom design to optimize group work. Altogether, the study supports the integration of ER in science curricula to enhance both cognitive and affective domains. It also calls for further research into ER's broader cognitive and affective benefits across diverse scientific and mathematical domains in elementary education.

5-1- Study Limitations and Future Lines of Research

This study presents a series of limitations that can be used in future studies. Regarding the questionnaires, it would be recommendable in future research to use questionnaires with the same nature of questions and answers, which would make it possible to verify whether the differences between both contents a consequence of this diversity are or of the characteristics of each content. In addition, it is necessary to evaluate the gender variable as an important factor in the learning of scientific content, so that future research should analyze this variable.

Similarly, future research should address the negative emotions presented by students in Educational Robotics-based interventions in order to mitigate them. In the same way, it would be advisable for future research to analyze scientific and mathematical knowledge in a qualitative manner, complementing the quantitative results, in order to determine the difficulties implicit in the relationships of the contents worked on. It also should be extended to longitudinal studies in order to provide a better generalization of the results obtained.

6- Declarations

6-1- Author Contributions

Conceptualization, A.H., L.M., and J.P.; methodology, A.H., L.M., and J.C.; software, A.H.; validation, L.M., J.P., F.C., and J.C.; formal analysis, A.H.; investigation, A.H., L.M., J.P., F.C., and J.C.; resources, A.H., L.M., F.C., and J.C.; data curation, A.H., F.C., and J.C.; writing—original draft preparation, A.H.; writing—review and editing, L.M., J.P., F.C., and J.C.; visualization, A.H.; supervision, L.M., J.P., F.C., and J.C; project administration, L.M., F.C., and J.C; funding acquisition, F.C. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available in the article.

6-3- Funding

This work has been 85% co-financed by the European Union, the European Regional Development Fund, and the Regional Government of Extremadura, the Managing Authority, and the Ministry of Finance, through project GR24052. This work was supported by National Funds through FCT-Portuguese Foundation for Science and Technology, I.P., under the scope of UIDEF — Unidade de Investigação e Desenvolvimento em Educação e Formação, UID/04107/2025, https://doi.org/10.54499/UID/04107/2025.

6-4- Acknowledgments

The Ministry of Science, Innovation and Universities Training is thanked for granting a predoctoral contract (FPU20/04959) and the financing of an international stay (EST24/00364).

6-5- Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the University of Extremadura. (139/2023, on September 28, 2023).

6-6- Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

6-7- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

7- References

[1] Flores Mejía, J. G., Velázquez Gatica, B., & Bernal Vargas, M. G. (2024). Divulgación científica en Educación Primaria: aplicación e innovación más allá del aula. Revista Eureka Sobre Enseñanza Y Divulgación De Las Ciencias, 21(3), 3207. doi:10.25267/Rev_Eureka_ensen_divulg_cienc.2024.v21.i3.3207. (in Spanish).

[2] Cuevas Romo, A., Hernández Sampieri, R., Leal Pérez, B. E., & Mendoza Torres, C. P. (2016). Enseñanza-aprendizaje de ciencia e investigación en educación básica en México. Revista Electrónica de Investigación Educativa, 18(3), 187–200. (in Spanish).

[3] Imaduddin, M., & Eilks, I. (2024). A scoping review and bibliometric analysis of educational research on water literacy and water education. Sustainable Chemistry and Pharmacy, 42, 101833. doi:10.1016/j.scp.2024.101833.

[4] Levy, A. R., & Mensah, F. M. (2021). Learning through the experience of water in elementary school science. Water (Switzerland), 13(1), 43. doi:10.3390/w13010043.

[5] Sadler, T. D., Nguyen, H., & Lankford, D. (2017). Water systems understandings: a framework for designing instruction and considering what learners know about water. Wiley Interdisciplinary Reviews: Water, 4(1), 1178. doi:10.1002/WAT2.1178.

[6] Cubero-Juánez, J., Sánchez-Herrera, S., Vallejo, J. R., Luengo, L., Calderón, M., & Bermejo-García, M. L. (2018). Aprendizaje cooperativo para la formación universitaria en alfabetización en salud. Revista de La Fundación Educación Médica, 21(2), 97. doi:10.33588/fem.212.938.

[7] Franco-Reynolds, L., De la Hoz Serrano, A., Valles Rapp, C., Benavente Sanguino, M. J., Sánchez Herrera, S., & Cubero Juánez, J. (2022). Efecto sobre el hábito de la dieta mediterránea de una intervención cooperativa en estudiantes universitarios TT. Rev. Esp. Nutr. Comunitaria, 28(4), 1–10. (in Spanish).

[8] Steven, A., Wilson, G., & Young-Murphy, L. (2019). The implementation of an innovative hydration monitoring app in care home settings: A qualitative study. JMIR MHealth and UHealth, 7(1), 9892. doi:10.2196/mhealth.9892.

[9] Gil, C. G. (2018). Objetivos de Desarrollo Sostenible (ODS): una revisión crítica. Papeles de relaciones ecosociales y caodsmbio global, (140), 107-118 (in Spanish).

[10] Rüegg, S. R., McMahon, B. J., Häsler, B., Esposito, R., Nielsen, L. R., Speranza, C. I., Ehlinger, T., Peyre, M., Aragrande, M., Zinsstag, J., Davies, P., Mihalca, A. D., Buttigieg, S. C., Rushton, J., Carmo, L. P., Meneghi, D. De, Canali, M., Filippitzi, M. E., Goutard, F. L., … Lindberg, A. (2017). A blueprint to evaluate one health. Frontiers in Public Health, 5(20). doi:10.3389/fpubh.2017.00020.

[11] Fuente-Ballesteros, A. (2023). Encuentros con ciencia: taller de experiencias en el laboratorio para aumentar el nivel de cultura científica en educación primaria. Faraday. Boletin de Física y Química (Segunda Época), 39(39), 11–15. (in Spanish).

[12] Angeli, C., & Valanides, N. (2020). Developing young children's computational thinking with educational robotics: An interaction effect between gender and scaffolding strategy. Computers in Human Behavior, 105, 105954. doi:10.1016/j.chb.2019.03.018.

[13] Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. Computers and Education, 72, 145–157. doi:10.1016/j.compedu.2013.10.020.

[14] del Olmo-Muñoz, J., Cózar-Gutiérrez, R., & González-Calero, J. A. (2020). Computational thinking through unplugged activities in early years of Primary Education. Computers and Education, 150. doi:10.1016/j.compedu.2020.103832.

[15] You, H. S., Chacko, S. M., & Kapila, V. (2021). Examining the Effectiveness of a Professional Development Program: Integration of Educational Robotics into Science and Mathematics Curricula. Journal of Science Education and Technology, 30(4), 567–581. doi:10.1007/s10956-021-09903-6.

[16] Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. Robotics and Autonomous Systems, 75, 661–670. doi:10.1016/j.robot.2015.10.008.

[17] Ching, Y. H., & Hsu, Y. C. (2024). Educational Robotics for Developing Computational Thinking in Young Learners: A Systematic Review. TechTrends, 68(3), 423–434. doi:10.1007/s11528-023-00841-1.

[18] Gaudiello, I. & Zibetti, E. (2016). Learning robotics, with robotics, by robotics: Educational robotics. John Wiley & Sons.

[19] Ziaeefard, S., Miller, M. H., Rastgaar, M., & Mahmoudian, N. (2017). Co-robotics hands-on activities: A gateway to engineering design and STEM learning. Robotics and Autonomous Systems, 97, 40–50. doi:10.1016/j.robot.2017.07.013.

[20] Sánchez, M. E., Gutiérrez, R. C., & Somoza, J. A. G. C. (2019). Robótica en la enseñanza de conocimiento e interacción con el entorno. Una investigación formativa en Educación Infantil. RIFOP: Revista interuniversitaria de formación del profesorado, 33(94), 11-28. (in Spanish).

[21] Marcos-Pablos, S., & García-Peñalvo, F. J. (2022). More than surgical tools: a systematic review of robots as didactic tools for the education of professionals in health sciences. Advances in Health Sciences Education, 27(4), 1139–1176. doi:10.1007/s10459-022-10118-6.

[22] Mellado, V., Borrachero, A. B., Brígido, M., Melo, L. V., Dávila, M. A., Cañada, F., Conde, M. C., Costillo, E., Cubero, J., Esteban, R., Martínez, G., Ruiz, C., Sánchez, J., Garritz, A., Mellado, L., Vázquez, B., Jiménez, R., & Bermejo, M. L. (2014). Emotions in science teaching. Ensenanza de Las Ciencias, 32(3), 11–36. doi:10.5565/rev/ensciencias.1478. (in Spanish).

[23] Del Rosal Sánchez, I., Dávila Acedo, M. A., & Cañada Cañada, F. (2022). Análisis de las emociones en estudiantes de Educación Primaria al abordar contenidos sobre "El ser humano y la salud." Ápice. Revista de Educación Científica, 6(1), 57–73. doi:10.17979/arec.2022.6.1.8656. (in Spanish).

[24] Mora, F. (2021). Neuroeducación: Solo se Aprende Aquello que se ama; Alianza Editorial: Madrid, Spain, 2021; ISBN-10 841362522X, ISBN-13 978-8413625225. (in Spanish).

[25] Bravo, E., Costillo, E., Bravo, J. L., Mellado, V., & Conde, M. del C. (2022). Analysis of prospective early childhood education teachers' proposals of nature field trips: An educational experience to bring nature close during this stage. Science Education, 106(1), 172–198. doi:10.1002/sce.21689.

[26] Dávila-Acedo, M. A., Sánchez-Martín, J., Airado-Rodríguez, D., & Cañada-Cañada, F. (2022). Impact of an Active Learning Methodology on Students' Emotions and Self-Efficacy Beliefs towards the Learning of Chemical Reactions—The Case of Secondary Education Students. Education Sciences, 12(5). doi:10.3390/educsci12050347.

[27] Hernández del Barco, M. (2023). Estudio longitudinal del rendimiento afectivo y cognitivo en la formación científica de docentes [Tesis de doctorado, Universidad de Extremadura]. Repositorio institucional-Universidad de Extremadura. Available online: https://dehesa.unex.es/handle/10662/17550 (accessed on December 2025).

[28] Romero, Y. N., Adúriz-Bravo, A., Tuay Sigua, R. N., & Pérez Mesa, M. R. (2024). La investigación sobre las emociones en la didáctica de las ciencias experimentales: momentos clave de consolidación. Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 21(3). doi:10.25267/Rev_Eureka_ensen_divulg_cienc.2024.v21.i3.3301. (in Spanish).

[29] Vázquez-Alonso, Â., & Manassero-Mas, M. A. (2011). El descenso de las actitudes hacia la ciencia de chicos y chicas en la educación obligatoria. Ciência & Educação (Bauru), 17(2), 249–268. doi:10.1590/s1516-73132011000200001. (in Spanish).

[30] Yllana-Prieto, F., González-Gómez, D., & Jeong, J. S. (2023). Teaching Scientific Content through a Methodology Based on Escape Room. Ensenanza de Las Ciencias, 41(3), 69–88. doi:10.5565/rev/ensciencias.5873.

[31] Bravo Lucas, E., Brígido Mero, M., Hernández Del Barco, M. A., & Mellado Jiménez, V. (2022). Emotions in science during the initial training of Early Childhood and Primary Education teachers. Revista Interuniversitaria de Formacion Del Profesorado, 97(36.1), 57–74. doi:10.47553/rifop.v97i36.1.92426.

[32] Çoban, G. Ü., Akpinar, E., Küçükcankurtaran, E., Yildiz, E., & Ergin, Ö. (2011). Elementary school students' water awareness. International Research in Geographical and Environmental Education, 20(1), 65–83. doi:10.1080/10382046.2011.540103.

[33] Covitt, B., Gunckel, K., & Anderson, C. (2009). Students' developing understanding of water in environmental systems. Journal of Environmental Education, 40(3), 37–51. doi:10.3200/JOEE.40.3.37-51.

[34] Arthur, B., Roberts, D., Rae, B., Marrison, M., McCleary, H., Abbott, A., & Musso, B. (2021). Ocean Outreach in Australia: How a National Research Facility is Engaging with Community to Improve Scientific Literacy. Frontiers in Environmental Science, 9, 610115. doi:10.3389/fenvs.2021.610115.

[35] Boyd, M., & Scott, G. W. (2022). An expert-led outdoor activity can have a lasting impact on the environmental knowledge of participating pupils and adults. Education 3-13, 50(5), 696–706. doi:10.1080/03004279.2021.1899261.

[36] Owens, D. C., Petitt, D. N., Lally, D., & Forbes, C. T. (2020). Cultivating water literacy in stem education: Undergraduates' socio-scientific reasoning about socio-hydrologic issues. Water (Switzerland), 12(10), 2857. doi:10.3390/w12102857.

[37] Mostacedo-Marasovic, S. J., Mott, B. C., White, H., & Forbes, C. T. (2023). Towards water literacy: Analysis of standards for teaching and learning about water on Earth. Journal of Geoscience Education, 71(2), 192–207. doi:10.1080/10899995.2022.2112490.

[38] Reyero, C., Calvo, M., Vidal, M. P., García, E. G., & Gabriel, J. (2007). Las ilustraciones del ciclo del agua en los textos de Educación Primaria. Enseñanza de Las Ciencias de La Tierra, 15(3), 287–294. (in Spanish).

[39] Ben-zvi-Assarf, O., & Orion, N. (2005). A study of junior high students' perceptions of the water cycle. Journal of Geoscience Education, 53(4), 366–373. doi:10.5408/1089-9995-53.4.366.

[40] Hernández, M. J. (2014). ¿Qué debería conocer todo ciudadano sobre el agua? Alambique: Didáctica de Las Ciencias Experimentales, 77, 9–16. (in Spanish).

[41] Ramírez-Segado, A., Rodríguez-Serrano, M., & Benarroch, A. B. (2020). Water in educative literature during the last two decades. A systematic review. Revista Eureka, 18(1). doi:10.25267/REV_EUREKA_ENSEN_DIVULG_CIENC.2021.V18.I1.1107. (in Spanish).

[42] Romine, W. L., Schaffer, D. L., & Barrow, L. (2015). Development and Application of a Novel Rasch-based Methodology for Evaluating Multi-Tiered Assessment Instruments: Validation and utilization of an undergraduate diagnostic test of the water cycle. International Journal of Science Education, 37(16), 2740–2768. doi:10.1080/09500693.2015.1105398.

[43] EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA) (2010). Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol. EFSA Journal, 8(3), 1461. doi:10.2903/j.efsa.2010.1461.

[44] Salas-Salvadó, J., Maraver, F., Rodríguez-Mañas, L., de Pipaon, M. S., Vitoria, I., & Moreno, L. A. (2020). The importance of water consumption in health and disease prevention: the current situation. Nutricion Hospitalaria, 37(5), 1072–1086. doi:10.20960/nh.03160.

[45] Benelam, B., & Wyness, L. (2010). Hydration and health: A review. Nutrition Bulletin, 35(1), 3–25. doi:10.1111/j.1467-3010.2009.01795.x.

[46] Chen, S. H., Huang, Y. P., & Shao, J. H. (2017). Effects of a dietary self-management programme for community-dwelling older adults: a quasi-experimental design. Scandinavian Journal of Caring Sciences, 31(3), 619–629. doi:10.1111/scs.12375.

[47] McCarroll, M., & Hamann, H. (2020). What we know about water: A water literacy review. Water (Switzerland), 12(10), 2803. doi:10.3390/w12102803.

[48] Hernández-Rabanal, C., Vall, A., & Boter, C. (2017). Training, the key to improving eHealth literacy of upper secondary school students. Gaceta Sanitaria, 32(1), 48-53. doi:10.1016/j.gaceta.2016.12.005.

[49] Mávita-Corral, C. J. (2018). Alfabetización en salud de una comunidad universitaria del noroeste de México en el año 2016. Investigación En Educación Médica, 7(25), 36–45. doi:10.1016/j.riem.2017.03.002. (in Spanish).

[50] Braslavsky, B. (2003). ¿Qué se entiende por alfabetización? Lectura y vida, Revista Latinoamericana de lectura, 24(2), 1-17. (in Spanish).

[51] George Reyes, C. E., & Avello-Martínez, R. (2021). Digital literacy in education. Systematic review of scientific production in Scopus. Revista de Educación a Distancia, 21(66). doi:10.6018/RED.444751.

[52] Fernando, D., Gualdrón, R., & Aldana, B. U. (2013). Alfabetización Digital en Salud: un Análisis del Constructo en la Escala "eHealth Literacy Scale _ eHeals" Traducida al Español. RevistaeSalud.Com, 9(36), 1698–7969. (in Spanish).

[53] Jaipal-Jamani, K., & Angeli, C. (2017). Effect of Robotics on Elementary Preservice Teachers' Self-Efficacy, Science Learning, and Computational Thinking. Journal of Science Education and Technology, 26(2), 175–192. doi:10.1007/s10956-016-9663-z.

[54] Ouyang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: a multilevel meta-analysis. International Journal of STEM Education, 11(1), 7. doi:10.1186/s40594-024-00469-4.

[55] Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. Computers and Education, 58(3), 978–988. doi:10.1016/j.compedu.2011.10.006.

[56] Jaipal-Jamani, K. (2023). Preservice teachers' science learning and self-efficacy to teach with robotics-based activities: Investigating a scaffolded and a self-guided approach. Frontiers in Education, 8, 979709. doi:10.3389/feduc.2023.979709.

[57] Sengupta, P., Kinnebrew, J. S., Basu, S., Biswas, G., & Clark, D. (2013). Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework. Education and Information Technologies, 18(2), 351–380. doi:10.1007/s10639-012-9240-x.

[58] Kyriazopoulos, I., Koutromanos, G., Voudouri, A., & Galani, A. (2022). Educational Robotics in Primary Education: A Systematic Literature Review. In C. Mehdi (Ed.), Research Anthology on Computational Thinking, Programming, and Robotics in the Classroom, 2, 782–806. doi:10.4018/978-1-6684-2411-7.ch034.

[59] Sáez-López, J. M., Sevillano-García, M. L., & Vazquez-Cano, E. (2019). The effect of programming on primary school students' mathematical and scientific understanding: educational use of mBot. Educational Technology Research and Development, 67(6), 1405–1425. doi:10.1007/s11423-019-09648-5.

[60] Cakir, N. K., & Guven, G. (2019). Arduino-Assisted robotic and coding applications in science teaching: Pulsimeter activity in compliance with the 5E learning model. Science Activities, 56(2), 42–51. doi:10.1080/00368121.2019.1675574.

[61] Scaradozzi, D., Cesaretti, L., Screpanti, L., Costa, D., Zingaretti, S., & Valzano, M. (2019). Innovative Tools for Teaching Marine Robotics, IoT and Control Strategies Since the Primary School. In L. Daniela (Ed.), Smart Learning with Educational Robotics (pp. 199–227). Springer. doi:10.1007/978-3-030-19913-5_8.

[62] Bampasidis, G., Piperidis, D., Papakonstantinou, V. C., Stathopoulos, D., Troumpetari, C., & Poutos, P. (2021). Hydrobots, an Underwater Robotics STEM Project: Introduction of Engineering Design Process in Secondary Education. Advances in Engineering Education.

[63] Liu, L., Oh, H., Zhang, L., Fang, T., Huang, M., Hao, Y., Wang, J., Yao, C., & Ying, F. (2023). A study of children's learning and play using an underwater robot construction kit. International Journal of Technology and Design Education, 33(2), 317–336. doi:10.1007/s10798-021-09720-3.

[64] Costa, D., Screpanti, L., & Scaradozzi, D. (2023). Disseminating STEM Subjects and Ocean Literacy through a Bioinspired Toolkit. Biomimetics, 8(2), 161. doi:10.3390/biomimetics8020161.

[65] De la Hoz, A., Melo, L., Álvarez, A., Cañada, F., & Cubero, J. (2023). The Promotion of Healthy Hydration Habits through Educational Robotics in University Students. Healthcare, 11(15), 2160. doi:10.3390/healthcare11152160.

[66] Damasio, A. R. (2010). Y el cerebro creo al hombre (p. 544).

[67] Sun, L., Hu, L., Yang, W., Zhou, D., & Wang, X. (2021). STEM learning attitude predicts computational thinking skills among primary school students. Journal of Computer Assisted Learning, 37(2), 346–358. doi:10.1111/jcal.12493.

[68] Selcuk, N. A., Kucuk, S., & Sisman, B. (2024). Does really educational robotics improve secondary school students' course motivation, achievement and attitude? Education and Information Technologies, 29(17). doi:10.1007/s10639-024-12773-1.

[69] Creswell, J. W. A (2014). A Concise Introduction To Mixed Methods Research. In Barataria. Revista Castellano-Manchega de Ciencias Sociales (Issue 18). SAGE publications.

[70] World Medical Association (WMA). (2010). Declaration of Helsinki: Ethical principles for medical research involving human subjects. In Human Dignity and Human Cloning, 243–248. doi:10.1515/9783110208856.233.

[71] Sun, L., & Liu, J. (2024). A gender differential analysis of educational robots' effects on primary teachers' computational thinking: Mediating effect of programming attitudes. Education and Information Technologies, 29(15), 19753–19782. doi:10.1007/s10639-024-12655-6.

[72] Castelltort, A. (2015). Educar a favor d'una nova cultura ambiental de l'aigua. Universitat Autònoma de Barcelona. (in Spanish).

[73] Márquez, C., & Bach, J. (2007). Una propuesta de ańalisis de las representaciones de los alumnos sobre el ciclo del agua [A study for analysing the students' representations on the water cycle]. Enseñanza de Las Ciencias de La Tierra, 15(3), 280–286. (in Spanish).

[74] Valle, M. G. (2017). El conocimiento del ciclo del agua en el segundo ciclo de Educación Primaria. Ikastorratza, e-Revista de didáctica, 18 : 20-44. (in Spanish).

[75] Verdugo, J., Solaz, J. & Sanjosé, V. (2019). Evaluación del Conocimiento Científico en Maestros en formación inicial: el caso de la comunidad Valenciana. Revista de Educación, 383, 133-162. (in Spanish).

[76] Bartrina, J. A., Arija Val, V., Maíz Aldalur, E., Martínez De Victoria Muñoz, E., Ortega Anta, R. M., Pérez-Rodrigo, C., Quiles Izquierdo, J., Rodríguez Martín, A., Román Viñas, B., Salvador I Castell, G., Tur Marí, J. A., Moreiras, G. V., & Majem, L. S. (2016). Guías alimentarias para la población española (SENC, diciembre 2016); la nueva pirámide de la alimentación saludable. Nutricion Hospitalaria, 33(8), 1–48. doi:10.20960/NH.827. (in Spanish).

[77] Martínez, J.R. and Iglesias, C. (2006). El libro blanco de la hidratación. Sociedad Española de Dietética y Ciencias de la Alimentación: Madrid, Spain. (in Spanish).

[78] Poulos, N. S., & Pasch, K. E. (2016). Socio-demographic differences in energy drink consumption and reasons for consumption among US college students. Health Education Journal, 75(3), 318–330. doi:10.1177/0017896915578299.

[79] Perales-García, A., Ortega, R. M., Urrialde, R., & López-Sobaler, A. M. (2018). Assessment of beverage consumption, dietary water intake and adequacy to the recommendations of a group of spanish schoolchildren from 7 to 12 years old. Nutricion Hospitalaria, 35(6), 1347–1355. doi:10.20960/nh.1995. (in Spanish).

[80] De la Hoz, A., Durán-Vinagre, M. A., Melo, L., Costillo, E., Luengo, R., & Cubero, J. (2021). Diseño de una página web para una formación innovadora de la alfabetización digital en salud. Congreso Internacional Alfabetización en Salud y Autocuidado. Evidencias que diseñan la práctica clínica, (28–29 April 2021), Bragança, Portugal.

[81] Taber, K. S. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. Research in Science Education, 48(6), 1273–1296. doi:10.1007/s11165-016-9602-2.

[82] De la Hoz Serrano, A., Sánchez, S., Vega, M. R., Sanguino, M. J. B., & Juánez, J. C. (2020). Análisis del hábito de hidratación y su conocimiento en una muestra escolares de 10-12 años en la provincia de Badajoz (España). Revista Española de Nutrición Comunitaria, 26(2), 2.

[83] Hernández del Barco, M. A., Cañada, F. C., Cordovilla Moreno, A. M., & Airado-Rodríguez, D. (2022). An approach to epistemic emotions in physics' teaching-learning. The case of pre-service teachers. Heliyon, 8(11), 11444. doi:10.1016/j.heliyon.2022.e11444.

[84] Varela, T. V, & Sutton, L. H. (2021). La codificación y categorización en la teoría fundamentada, un método para el análisis de los datos cualitativos. Investigación En Educación Médica, 10(40), 97–104. (in Spanish).

[85] Ocaña, R. (2019). Descubriendo R-Commander, (3ª ed). Escuela Andaluza de Salud Pública (EASP), Andalucía, Spain. (in Spanish).

[86] Costa, A., Sánchez-Gómez, M., & Martín, M. (Eds.). (2020). La Práctca de la investgación cualitatva: ejemplifcación de estudios (2ª Edi), Ludomedia. (in Spanish).

[87] Bocconi, S., Chioccariello, A., Kampylis, P., Dagienė, V., Wastiau, P., Engelhardt, K., Earp, J., Horvath, M., Jasutė, E., Malagoli, C., Masiulionytė-Dagienė, V., & Stupurienė, G. (2022). State of play and practices from computing education Reviewing Computational Thinking in Compulsory Education. Publications Office of the European Union. Available online: https://bit.ly/4dHaoqE (accessed on December 2025).

[88] De la Hoz, A., Cubero, J., Melo, L., Durán-Vinagre, M. A., & Sánchez, S. (2021). Analysis of Digital Literacy in Health through Active University Teaching. International Journal of Environmental Research and Public Health, 18(12), 6674. doi:10.3390/ijerph18126674.

[89] Sujana, A., Rachmatin, D., & Panjaitan, R. L. (2019). Science and mathematics literacy of elementary school students related to water cycle. Journal of Physics: Conference Series, 1318(1). doi:10.1088/1742-6596/1318/1/012131.

[90] Oguta, S., Ojo, S., & Maake, B. (2025). Prototype Implementation of a Robotic Gamification Model for Climate Change Literacy for Green Innovation and Entrepreneurship with Social Robot Nao. International Journal of Computing Sciences Research, 9, 3491–3523. doi:10.25147/ijcsr.2017.001.1.230.

[91] Koray, A., & Duman, F. G. (2022). Subject-oriented educational robotics applications with Arduino in science teaching: digital dynamometer activity in accordance with 5E instractional model. Science Activities, 59(4), 168–179. doi:10.1080/00368121.2022.2093824.

[92] Koray, A., & Uzuncelebi, B. H. (2023). The Effect of Educational Robotics Applications on Students' Academic Achievement and Problem-Solving Skills in Science Education. Journal of Education in Science, Environment and Health, 9(4), 317–329. doi:10.55549/jeseh.1381251.

[93] Ntourou, V., Kalogiannakis, M., & Psycharis, S. (2021). A Study of the Impact of Arduino and Visual Programming In Self-Efficacy, Motivation, Computational Thinking and 5th Grade Students' Perceptions on Electricity. Eurasia Journal of Mathematics, Science and Technology Education, 17(5), 1–11. doi:10.29333/ejmste/10842.

[94] Li, S. R., & Chang, Y. J. (2024). Effectiveness of a nutrition education intervention using simulation videos and encouragement of parental involvement for elementary school students. Journal of Nutritional Science, 13, 35. doi:10.1017/jns.2024.41.

[95] Breil, C., & Lillich, M. (2024). Health literacy education of children in Austrian elementary schools. Health Education Research, 39(1), 29–39. doi:10.1093/her/cyad022.

[96] Öksüz, Y., & Güven Demır, E. (2019). Comparison of open ended questions and multiple choice tests in terms of psychometric features and student performance. Hacettepe Egitim Dergisi, 34(1), 259–282. doi:10.16986/HUJE.2018040550.

[97] Conde, M., Rodríguez-Sedano, F. J., Fernández-Llamas, C., Gonçalves, J., Lima, J., & García-Peñalvo, F. J. (2021). Fostering STEAM through challenge-based learning, robotics, and physical devices: A systematic mapping literature review. Computer Applications in Engineering Education, 29(1), 46–65. doi:10.1002/cae.22354.

[98] López-Belmonte, J., Segura-Robles, A., Moreno-Guerrero, A. J., & Parra-González, M. E. (2021). Robotics in education: A scientific mapping of the literature in web of science. Electronics (Switzerland), 10(3), 1–18. doi:10.3390/electronics10030291.

Appendix I. Robotic Boards

Appendix II. Water Cycle Questionnaire

1. **What is the difference between the oceanic zone and the continental zone?**

   a) In the continental zone, there is less precipitation than evaporation.

   b) In the oceanic zone, there is less precipitation than evaporation.

   c) Both in the oceanic and continental zones there is the same amount of precipitation and evaporation.

   d) There is no relationship between evaporating and precipitating water.

2. **In the Water Cycle:**

   a) The water circulates in one direction only until the cycle is completed.

   b) The Water Cycle starts in the mountains and ends in the oceans.

   c) The Water Cycle has many directions, and water changes state and phase throughout the cycle

   d) The water in the ocean grows every day because the water in the rivers flows into the ocean

3. **What are clouds composed of?**

   a) Water vapor

   b) Water droplets

   c) Other substances (ice crystals, dust...)

   d) All are correct

4. **Cloud formation occurs:**

   a) After evaporation, when water vapor rises into the atmosphere.

   b) After evaporation, when the water vapor gathers together

   c) líquida After condensation, when liquid water droplets are brought together

   d) After condensation, when water droplets are formed and concentrated with other elements such as ice crystals, dust, water vapor...

5. **In the Water Cycle, we can say that plants:**

   a) Like people, have no influence on the Water Cycle.

   b) Influences the Water Cycle thanks to transpiration.

   c) They perform transpiration, but it does not affect the Water Cycle

   d) Plants alter water quality.

6. To what extent do living things affect the water cycle?

a) Plants influence the storage of water and produce changes in the state of absorbed water.

b) Humans, although we use water, do not change the path or quantity of water.

c) Human activities and constructions alter the natural water cycle

d) A and C are correct

7. Which of these actions affect water availability?

a) Buying a lot of clothes

b) Cutting down a lot of trees

c) Frequently changing phones, computers...

d) All are correct

8. Where is groundwater found?

a) Only in humid climates

b) Only where there is soil, since water cannot move through rock

c) Groundwater can exist in rock or soil, but is not found below the earth's surface.

d) Almost anywhere below the earth's surface.

Appendix III. Habit of Healthy Hydration Questionnaire

a) How many glasses of water should you drink at least once a day?

b) How much water is recommended to drink daily?

c) Through the intake of solid foods, how much percentage of water do we obtain for hydration of the body?

d) Are there any differences between natural and bottled juice? Explain the differences between the two and how much of each you can drink per day.

e) What is the main function of water in the body?

f) Indicate 5 benefits of hydrating correctly

Appendix IV. Category System of Emotions Questionnaire

Dimension	Category	F	%	Example
Boredom	Timing	10	50%	When we already had the job and had to wait
	Partners	6	30%	When colleagues were unhelpful or annoying
	Not specified	4	20%	Sometimes, but few times
Surprise	Start	10	20%	The first day, not knowing what we were going to do.
	Functioning	10	20%	When I saw what the robot was doing and it was working
	Construction	7	14%	When I assembled the robot
	Learning	5	10%	Because I thought the natural juice had less sugar in it
	Resolution	5	10%	When we did not know how to assemble the robot and I put that piece that held the paper
	No response	13	26%	-
Anger	Partners	16	61.54%	When colleagues would not allow a girl in the group to do anything
	No response	10	38.46%	-
Fun	Construction	15	20.83%	While assembling the robot
	Partners	4	5.56%	When we were working as a group
	Programming	10	13.89%	When we started with Micro:bit®
	Not specified	4	5.56%	Almost every day
	No answer	39	54.17%	-
Nervousness	Ignorance	6	17.14%	At the beginning. I didn't know if I was going to be bored or entertained.
	Exposure	12	34.29%	When we had to expose our colleagues
	Functioning	5	14.28%	When we had to finish and the program was not going well.
	No response	12	34.29%	-
Joy	Start	5	6.94%	In the beginning
	Functioning	13	18.06%	When the robot did what we wanted
	Exposures	6	8.33%	When we presented as a group very well
	Partners	4	5.56%	For working with my classmates
	Methodology	4	5.56%	It's better than the book
	Not specified	8	11.11%	Doing robotics
	No response	32	44.44%	-

* F=Frequency; %=Percentage of each emotion.