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# Emotions and interests in social representations about the environmental problem of arsenic in water in Tandil (Buenos Aires, Argentina)

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Qualitative research is presented, recovering the discourse of the students. We worked with a survey and an interview in a 7th year course of the Chemistry Technical at a secondary school in Tandil with a population of 20 people. The first, as a qualitative technique, used those points from the ROSES questionnaire and some items, associated with the theme of arsenic in water, were added in order to incorporate the components of the representations where emotions can be found. On the other hand, the qualitative interview, evoked from images, used a set associated with the theme (water filters, cartographic maps, images of the disease, among others). This created a better communication with the students as well as other aspects. The students had to classify an image in relation to the following items: sadness, fear, distrust, helplessness, anger, worry and indifference. The selection of those emotions was based on previous studies conducted on social representations of environmental issues, such as climate change. The results obtained showed that the students have a great interest in environmental issues and recognize their active role in relation to solving these aspects. In addition, it was obtained that more than 80% of the students expressed their interest in learning more about the subject. Likewise, in relation to the images, the students expressed the following emotions: sadness, helplessness, worry and fear. Faced with these results, the different emotions are taken into account at stake for the subsequent development of a contextualized didactic sequence in the city of Tandil, with the aim of working on the problem of arsenic in water and the emotions obtained from the interview.

KEYWORDS

**emotions, interests, social representations, arsenic in water, one health**

## 1 Introduction

### 1.1 Environmental education from the scientific, technological and social perspective

Education about the environment was in its beginnings linked to ecology and a conservationist and biologist perspective (Corbetta, 2021). In 1977 the World Conference of Environmental Education (EE) was held in Tbilisi, where an interdisciplinary and transversal EE was proposed in different areas, which addressed environmental complexity in relation to

the possibility for citizens to make decisions in connection with their relationship with the environment. EE was the object of deep struggles over its direction and focus until it was consolidated as a multidisciplinary field of study (González-Gaudiano and Lorenzetti, 2009). Today, there is a consensus in Latin America to work on EE based on case studies that allow students to integrate concepts to understand each environmental problem from science and its relationship with society (Coló Andrade and Irazoque Palazuelos, 2023).

In Argentina, the Act 27621 was enacted on May 13, 2021: "Act for the implementation of Comprehensive Environmental Education in the Argentine Republic." The purpose of this law is to establish the obligation of Environmental Education (EE) at all levels and modalities of the National Educational System focusing on the formation of environmental awareness that contributes to citizen education and the exercise of the right to a healthy, dignified and diverse environment. The Act allows incorporating EE in subjects in which curricular designs do not incorporate the theme. For this reason, the training of Social and Natural Science teachers is changing due to the modification of the study plans and the incorporation of the Scientific, Technological and Social (STS) perspective to address environmental issues (Dirección General de Cultura y Educación de la Provincia de Buenos Aires, 2022a,b,c). The Biology teaching staff includes the subject "Environmental Education" in the second year (Dirección General de Cultura y Educación de la Provincia de Buenos Aires, 2022a), the Chemistry teaching staff includes the subject "Chemistry, Environment and Society" where the regulatory framework is provided to address EE (Dirección General de Cultura y Educación de la Provincia de Buenos Aires, 2022b), the Physics teaching staff includes "Physics, Technology and Environment" where the scientific-technological topics selected will be treated in the context of environmental problems and conflicts, from an integrative vision that contemplates social, natural and technological aspects (Dirección General de Cultura y Educación de la Provincia de Buenos Aires, 2022c). The incorporation of subjects on EE is accompanied by the transversality of environmental topics in all subjects of the study plan. The new teachers have based the implementation of EE on the provisions of Article 2 of the Law, which establishes as a definition that "(…) it is a process that defends sustainability as a social project, the development with social justice, the distribution of wealth, preservation of nature, gender equality, health protection, participatory democracy and respect for cultural diversity" (Dirección General de Cultura y Educación de la Provincia de Buenos Aires, 2022a,b,c). In this sense, it seeks to train teachers in scientific literacy proposals and to incorporate emotion in their classrooms in relation to environmental problems that affect the population. For example, one of the topics mentioned is the development of environmental awareness for the environmental problems in the Province of Buenos Aires. In the context of scientific education for the scientific literacy of students, Adúriz-Bravo (2012) proposes three key competences in the development:

a. Competences specific to Natural Science that make it possible to distinguish it from the other dimensions of culture, particularly everyday knowledge.
b. Generic citizen competences in which the Natural Sciences are barely a context.
c. Epitome, key, paradigmatic or central competencies at the disciplinary and meta-disciplinary level, for the formative teaching and learning processes, such as those that use science models, communication/argumentation, and mastery of science procedures.

In this perspective of intercultural EE and development of scientific literacy the STS approach has a key place. On the other hand, EE must be transversal to different topics and include in its approach local environmental problems, environmental conflicts generated, intervening social actors, solutions from the State, public policies to guarantee a healthy environment (Telias et al., 2014). In this context, EE proposes to reestablish, from a critical perspective, the relationship between human beings, society and nature, from a more sustainable perspective with access to sustainable resources and with the possibility of a state present in environmental problems (Telias et al., 2014).

The teaching of environmental issues cannot be reduced to learning a set of scientific knowledge or procedures without taking a critical position and fostering feelings in the face of current situations (Rebelo et al., 2006). In this sense, the STS teaching is proposed as an alternative to work on specific situations that surround the students. In this way, STS education is constituted as an approach to EE from a comprehensive perspective (Porras Contreras et al., 2014). EE presents a great diversity of approaches, theories, methodologies and teaching strategies (Porras Contreras et al., 2014). However, these approaches, theory, methodologies and teaching strategies can be unified within STS education. Following Porras Contreras et al. (2014), these subfields for EE can understand the social world in Bourdieu's terms, in fields (artistic, political, scientific, legal, literary, environmental, etc.), for education, which make up:

> "A network or configuration of objective relationships between positions. These positions are objectively defined in their existence and in the determinations they impose on their occupants, whether agents or institutions, by their current and potential situation (situs) in the structure of the distribution of the different species of power (or capital)—whose possession implies access to the specific gains that are at stake within the field—and, incidentally, by its objective relations with other positions (domination, subordination, homology, etc.)" (Bourdieu and Wacquant, 1995, p. 64).

STS education provides an integrative and diverse perspective for the purposes of social justice and health for EE. Following Garritz (1994), the STS approach is not a special form of education (such as environmental education, education for health, etc.), it is also not a way to organize content in the curriculum or to select it. Otherwise, it is an educational reform that involves modifying the contents to work on those that are relevant to the population and therefore, it constitutes an appropriate approach to work on EE in a contextualized, real way and for the development of critical thinking.

In the words of Martins (2022):

> "Talking about science teaching in STS/STSE is talking about a school that was alive in its time, making students recognize the value of added knowledge to understand the world and also foreseeing the future effects of actions that remain unanswered. Do something in the present. It is also about curricula, disciplinary programs or training spaces that are not limited to each other; they interact and complement each other in an interdisciplinary

> vision. Problems and situations are not defined by disciplines. They are interpretations that are often given, without any concern, to help the student understand why this is so" (Martins, 2022, p. 168).

Following the STS taxonomy of Vázquez Alonso and Manassero-Mas (2020), working on the influence of science and technology on society makes it possible to address social decisions, social problems, economic well-being and problem solving. In this sense, the approach to EE from the STS perspective is fundamental for the development of scientific competences and to promote scientific literacy.

From the STS perspective, one of the approaches that seeks to promote is EE from the perspective of "One health." That is, characterizing and considering human, environmental and animal health as one. The EE, based on "One health," can contribute to the construction of different paths to achieve lifestyles that support ecological integrity, social and economic justice, sustainable ways of life and respect for all forms of life (Lampert, 2022). The EE, accompanied by "One health," had its roots at the beginning of the 21st century with the so-called "Sustainability Science" as a result of the unsustainable increase in environmental problems (Vilches Peña and Gil Pérez, 2015) in the educational field, is called Education for Sustainability (Vilches and Gil Pérez, 2013). A fundamental point of the interaction between society and nature in the face of the increase in different environmental problems is health, since it is determined by the environment where one lives. In this sense, it is important, when talking about health education, not only to define it as humans well-being, but also to define human, animal and ecosystem health as a whole (Arrivillaga and Caraballo, 2009). This is how the "One health" approach (Marcos, 2013) emerged to promote the interaction of animal, human and environmental health (Arrivillaga and Caraballo, 2009).

Environmental education from the perspective of "One health" allows promoting a global attitude towards science that is possible to know from social representations.

Manassero and Vázquez (1995) proposed a taxonomy to classify the potential objects of "science-related attitudes." This taxonomy categorizes the multiple and different attitudinal objects and scientific interests in three basic dimensions and seven sub-dimensions integrating science and technology (S&T):

- Attitudes towards teaching and learning: S&T at school and S&T products at school.
- Attitudes towards the interaction between science, technology and society: the social image of Science and Technology and the social aspects of Science and Technology.
- Attitudes towards the particularities of scientific and technological knowledge: the characteristics of scientists and technologists, social constructivism in S&T and the nature of S&T.

The understanding of the attitudes and interests on S&T, allows knowing the perspective, the position and the interest on a certain subject and, together with the emotions, the social representations have been recognized on the subject.

Scientific education, to promote correct scientific literacy among citizens, must address environmental and health aspects. For this reason, it is essential to incorporate EE from a perspective that allows working in multiple areas. As a summary, Figure 1 summarizes the theoretical framework from which EE is positioned in Argentina.

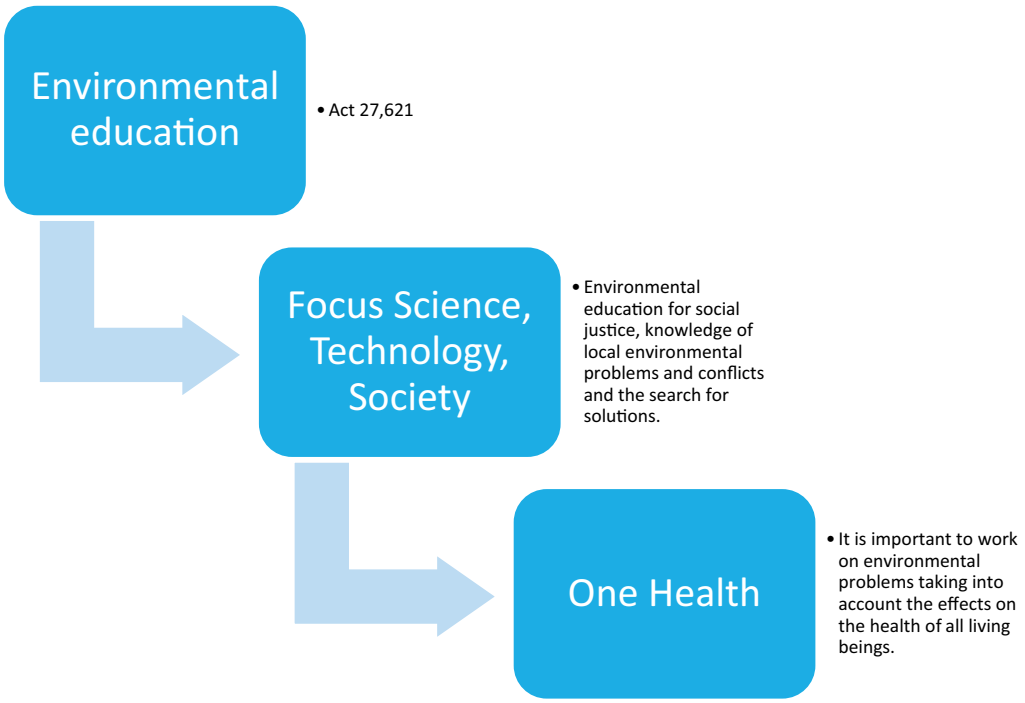


FIGURE 1
Environmental education in Argentina.

## 1.2 Social representations and emotions in environmental education

Social representations refer to the "common sense knowledge" that a person presents on a certain topic that allows characterizing their position regarding various aspects of daily life (Flores and Amigón, 2018). Moscovici (1979) states that social representations encompass three aspects: information and knowledge, the field of representation, and attitude and emotion, which, when integrated, constitute social representations.

> "Social representations are a network of interacting concepts and images whose content continually evolves over time and space. How the network evolves depends on the complexity and speed of communication, as well as on the means of communication available. Their social characteristics are determined by the interactions between individuals and/or groups, and the effect they have on themselves as a function of the relationship that unites them" (Moscovici, 1988, p. 220).

For his part, Jodelet (2006) indicates that these dimensions include images, expressions of values, beliefs and opinions about the feeling on a specific topic.

Social representations acquire a fundamental role in environmental education since they refer to the cognitions that stamp the collective thought of society and inform about a global vision that a society establishes itself around the sensations about certain aspects of life (Höijer, 2011).

In previous studies on social representations of environmental education, or of specific topics such as water, anthropocentric views arise that suggest the need to rethink environmental education with a broader view in the training of teachers and education professionals with a critical and global approach (Flores and Ramírez-Sosa, 2022).

The emotional component in the social representations of environmental problems is essential for the contextualization of teaching. For this reason, some authors talk about the "environmentalization" of environmental education taking into account the context in which a certain environmental problem or environmental conflict is experienced (Eschenhagen, 2007). For this reason, scientific literacy plays an essential role when it comes to understanding environmental phenomena (Porro, 2022) and it allows the school to be positioned as a space that activates awareness and emotions about the eco-efficiency of a territory (Arias, 2023). In this way, it allows modifying the reconfiguration of the territory and the human being-nature relationship as the body-culture-education relationship (Arias, 2023).

Following Vilhunen et al. (2022) and Shen et al. (2022), emotions in education are key to the development of experiences and training proposals that can foster meaningful and contextualized learning. For this reason, when teaching an environmental topic, it is not only enough to know the causes, consequences and effects of the environmental problem, but also to understand the feeling generated in people in order to promote environmental education with social justice (Pineda-Martínez et al., 2023).

Flores and Amigón (2018) say that some emotions must be considered in contextualized environmental education. The following list arises from the work of these authors and from the experience of the authorship team of the present article in relation to environmental education in the territory (Carballo et al., 2023):

- Indignation: anger at the state of the environment and a lack of harmony is presented between daily reality and the official discourse.
- Sadness: negative state of mind about the reality that is lived.
- Fear: assessment of aspects of the environment as negative because it can cause personal harm or damage to society in general.
- Mistrust: lack of security about the existence of healthy surroundings in the environment.
- Helplessness: emotion associated with the fact that little or nothing can be done to reverse a negative environmental situation.
- Anger: advanced state of indignation and impotence.
- Interest: proposal to be able to act to solve a negative environmental situation.
- Happiness and joy: positive status on an environmental issue that will not generate negative effects at an individual or collective level.

In science teaching, the emotions generated in the student are closely linked to the image of science, so much so that textbooks occupy a fundamental place when it comes to generating interest and feelings about the topics to be taught (Arango, 2020). The images allow us to understand the stereotypes and, at the same time, the emotion generated by them beyond the conceptual content (Arango, 2020). The images that are included in the teaching of sciences are bearers of meaning and contribute to the creation of a conception (Arango, 2020). It is important to mention the contribution of Simone (2001) who states that the natural vision offered by an image prevails over the alphabetic vision of the written letter, changing the hierarchy of the senses and consequently increasing the value of the image, which allows understanding the social representation itself on a certain theme.

## 1.3 The presence of arsenic in water: an environmental problem of emotional and educational importance

Environmental pollution is defined as the presence of foreign substances, energy or organisms in a given environment in quantities, time and conditions such that they cause ecological imbalance (Díaz and Pantoja, 2011). Pollutants can be classified following two criteria: their origin and the type of pollutant. Depending on the origin, the contaminants can be anthropogenic or natural. While, according to the type of contaminants, they can be physical, chemical or biological (Díaz and Pantoja, 2011). In all cases, these are environmental problems that can affect society. Arsenic is a contaminant of natural origin, mostly, and of a chemical type.

Arsenic in water is a worldwide problem that is caused by the presence of the contaminant in water for human and animal ingestion. Arsenic (As) is a metalloid (that is, a chemical element that presents intermediate characteristics between metals and non-metals) found in water, soil, and air, as it is one of the most abundant elements on earth. Chemically, it has atomic number 33 and four oxidation states (−3, 0, +3 and +5) which allows it to form different organic and

inorganic compounds. As it can be found in the air, soil and water it therefore affects people's health. In the case of the air, the presence of As is due to anthropogenic actions. While, in the case of As in water, its origin is due to geogenic issues from suspended dust derived from the soil or from volcanic emissions. In Argentina, the problem of water contamination with As is due to the existence of volcanic fragments present in underground loessians sediments (Pasquini, and Lecomte, 2018). It is important to note that, although its origin is mostly geological, there are economic activities such as mining, livestock and the use of agrochemicals that also influence As contamination in water, soil and air.

Arsenic is a chemical contaminant of water and food; the Argentine Food Code establishes the limits for the presence of contaminants in a product, such as water, to be innocuous. That is, it does not affect people's health and it does not generate a foodborne disease (FD).

Arsenic generates an FD known as chronic regional endemic hydroarsenicism (CREH). This disease usually manifests skin lesions and generates complex diseases in the population that is exposed for a long time to the entry of As into their body. It is important to note that As in water not only enters through the drink that a person can consume, but also through the water that is used to feed livestock or grow plant species. For this reason, it is essential to characterize this environmental problem from the "One health" approach that considering human, animal, and environmental health as a single one. Under the approach of "One health," characterizing the problem of CREH is proposed from a global and interdisciplinary perspective. For example, if CREH is characterized only by its effects on the human organism and its entry from drinking water, or if other routes of entry would remain to be analyzed.

In Argentina, in the province of Buenos Aires, different investigations were carried out that showed that the As situation in different locations is very critical (RSA (Red de Seguridad Alimentaria del CONICET), 2018; Miglioranza, 2021; Lampert, 2022). In the three publications, the presence of As in water was categorized into four ranges that go from R-1 to R-4 according to the level of As concentration in water, with R-1 being the range that ensures the safety of the water in compliance with the Argentine Food Code.

The As in Water theme is included in some high school curriculum designs. But only in those that have a Natural Sciences orientation and, specifically, within the subject "Environment, Development and Society" (Lampert and Porro, 2019). Which means that only a part of the secondary school population can address this topic. Likewise, returning to what was established by Arango (2020), the topic of As in water is presented with conceptual errors and incompletely in textbooks. It is presented as a problem that has no solution and without explaining the role of the state in solving it.

In a previous investigation, an analysis was carried out about the risk of FD on secondary school students and, more specifically, on the presence of arsenic in it. The results obtained showed that there is a significant lack of knowledge on the part of the population under study. However, in this research the emotional aspect was not incorporated into the subject (Lampert and Porro, 2021). This work aims to know the social representations about a global problem that is water contamination with arsenic of geological origin, but by incorporating the emotional component that the theme generates within the framework of the Project "The Relevance of Science Second Education" (ROSES).

### 1.4 The relevance of science education for the 21st century in Spain and Latin America

The Relevance of Science Second Education (ROSES) is an international comparative research project aimed at illuminating the factors of importance, interest and motivation for the teaching and learning of S&T in secondary schools from the direct voice of the student body. A wide range of countries from all continents participate in ROSES with special emphasis on Ibero-American countries. Research groups at institutions and individuals work together within the academic context to develop theoretical perspectives, research instruments, data collection, and educational proposals consistent with project results in order to give rise to student voice in the classroom. The target population is students at the end of their secondary education (over 15 years old) because they can look back on their education and reflect on what they have learned, and have not learned, about S&T. ROSES is an exploratory study leading to results that must be adapted to cultural considerations and pre-requisites.

The general objective of this ROSES project is to give students a voice to gather empirical knowledge about the affective contexts of S&T education, which means being able to include emotions in science teaching.

The basis of the ROSES questionnaire is its predecessor, ROSE, which has been extensively described in previous publications (Sjøberg and Schreiner, 2019). The questionnaire is created from different questions that have to establish a degree of assessment. All questions are simple and self-evident and simultaneously integrate cognitive, affective, and behavioral components. In relation to Environmental Education, the questionnaire presents a section called "Me and the environmental challenges" where the points of view of students in relation to environmental challenges are explored. Being able to know the attitudes and feelings in relation to the different challenges and environmental problems is fundamental. In the words of Manassero-Mas and Vázquez-Alonso (2023):

> "Proactive environmental attitudes focus on avoiding the harmful consequences that environmental indifference can have for oneself and for other human beings (anthropocentrism) or for the biosphere (ecocentrism), although various authors highlight the holistic nature of the different dimensions of environmental attitudes. And others still add some more, such as environmental indifference and emotional affinity" (Manassero-Mas and Vázquez-Alonso, 2023, p. 372).

## 2 Research development and methodological considerations

As previously mentioned, this research is part of the STS teaching paradigm and seeks to know the social representations of students (including cognitive, attitudinal and affective components) on the environmental problem of arsenic in water in Tandil. For this reason, we worked with a group of 20 students of the last year of a school in Tandil in two stages: on the one hand, the analysis of the social representations of the students and, on the other hand, the development of a didactic sequence STS that starts from their emotions.

We worked with a secondary school in Tandil because it is the only one in the town that has an orientation in Chemistry and has a very great interest in local environmental problems. The sample of 20 students is due to the fact that it is the only school that has this orientation in the entire town. The school's interest in working on the As problem is due to the fact that the students were reading an article that presented the following information: "A significant percentage of the samples have arsenic concentrations higher than the limit currently established in the Argentine Food Code of 0.01 mg/L. Taking into account that many of the drillings from which the samples were extracted are intended for human consumption, including in educational establishments, it is relevant to have this data to contrast it with an evaluation of health effects" (Barranquero et al., 2012, p. 10). For this reason, following the guidelines of Act 27621, it was proposed to work on a local environmental problem and learn about the representations that the students presented on the subject.

This research presents the methodological approach of the ROSES Project. In this approach, the students have to answer the following question for each phrase within the category "me and the environmental challenges": to what extend do you agree with the following statements? (Manassero-Mas and Vázquez-Alonso, 2023). Also, some of our own questions about the issue have been added, as it is shown below;

Specific questions of the ROSES project:

1. Threats to the environment are none of my business.
2. Environmental problems make the future of the world look bleak and hopeless.
3. Science and technology can solve all the environmental problems.
4. I am willing to see environmental problems solved, even if this means giving up many things.
5. I can personally influence what happens to the environment.
6. We can still find solutions to our environmental problems.
7. People worry too much about environmental problems.
8. Environmental problems can be solved without major changes in our way of living.
9. People should care more about protecting the environment.
10. Solving the world's environmental problems is the responsibility of rich countries.
11. Environmental problems should be left to the experts.
12. I feel optimistic about the future.
13. Almost all human activities harm the environment.

Added questions:

14. Arsenic in water is an environmental problem.
15. Arsenic in water affects the area where I live.
16. The State deals with the situation of arsenic in water.
17. A greater approach to the issue of arsenic in water in schools is needed to raise awareness about it.
18. The problem of arsenic in water limits the fulfillment of Human Rights.

The responses of the degree of agreement are collected on a four-point Likert scale (1-disagree, 2, 3, 4-agree) that represents the attitude of each student on each environmental aspect surveyed. In addition to the ROSES project methodology, two open questions were asked that allowed knowing the content and information on the subject: "What is the environmental problem of arsenic in water? What is its cause? This tool was designed in order to work on a specific environmental problem and was validated by experts in education, geography, chemistry, engineering and sociology. The categories developed for the analysis of emotions were obtained from previous works and from the analysis obtained by the CONICET Red de Seguridad Alimentaria (2018), which establishes the representations that society presents about this environmental problem.

After finishing the questions and the survey, the general guidelines of the problem of arsenic in water were explained, so that the student body could know what it is about and what its effects are. From this, following the methodology of Flores and Amigón (2018) on emotions in relation to the social representations of climate change, a qualitative interview was carried out, evoked from images related to the problem of As in water. It should be pointed out that the students must have minimal knowledge on a topic in order to be able to analyze the emotional factor. The images were presented to the students, so that they would report the impact that they caused them, based on the following emotions: indignation, sadness, fear, distrust, impotence, anger, interest, tranquility, happiness and joy. Students were allowed to choose more than one emotion related to the image.

Then they talked freely about the problem and their perception of the solution. The information obtained was analyzed looking for regularities in the expressions through content analysis (Bardín, 1986).

The selected images and their descriptions are presented in a box within the Supplementary material section.

## 3 Results

In relation to the results of the ROSES project, Table 1 is presented and Figure 2 summarizes the statistical data obtained.

In relation to interests and attitudes regarding the problem of arsenic in water, the following results were obtained (Table 2) and Figure 3 summarizes the statistical data obtained.

## 4 Discussion

Among the results, you can see the degree of interest that students have in environmental issues. For example, a 100% of the students consider that environmental problems are their business and assume the role of personally influencing what happens to the environment. On the other hand, the students show an optimistic view as they consider that solutions to the environmental problems can still be found, despite having to live without different things. They also emphasized that not only rich countries and experts should deal with the environmental issues, but also ordinary people should do something about it.

Those items that had differences between agreement and disagreement are associated with the role of S&T in solving environmental problems and with the idea that one cannot continue living in the same way in order to solve environmental problems. On the other hand, the 80% of the students do not have an optimistic view of the future and this is one of the items that teachers should be concerned about since it is important to form a critical citizen that can be incorporated and have hope in daily activities.

TABLE 1 ROSES project categories related to the environment.

| ROSES project categories related to the environment | Percent agree | Percent disagree |
|---|---|---|
| 1. Threats to the environment are none of my business | 0% | 100% |
| 2. Environmental problems make the future of the world look bleak and hopeless | 100% | 0% |
| 3. Science and technology can solve all the environmental problems | 40% | 60% |
| 4. I am willing to see environmental problems solved, even if this means giving up many things | 100% | 0% |
| 5. I can personally influence what happens to the environment | 100% | 0% |
| 6. We can still find solutions to our environmental problems | 100% | 0% |
| 7. People worry too much about environmental problems | 20% | 80% |
| 8. Environmental problems can be solved without major changes in our way of living | 50% | 50% |
| 9. People should care more about protecting the environment | 100% | 0% |
| 10. Solving the world's environmental problems is the responsibility of rich countries | 0% | 100% |
| 11. Environmental problems should be left to the experts | 0% | 100% |
| 12. I feel optimistic about the future | 20% | 80% |
| 13. Almost all human activities harm the environment | 100% | 0% |

In relation to the issue of arsenic in water, half of the students know arsenic in water as an environmental problem. When the open question was asked "What is the environmental problem of arsenic in water?" What is its cause? Only one person answered it, indicating that it was a chemical contaminant that could affect health, while the rest indicated that it was an environmental contamination problem that affects other countries.

Another striking fact was that all the students are unaware of the situation that occurs in their town. This is another result that allows us to strengthen the importance of contextualized STS education for students, since there is a lack of knowledge of the environmental problems that affect them in the place where they live.

On the other hand, the total amount of the students indicated that a wider approach of As in water issue is needed at school in order to become aware of this problem which also affects the Human Rights compliance.

In relation to the second part, the images allowed us to understand the emotions and the interest and the disinterest in the different topics.

In Supplementary material (Image 1, water filter), the students raised the following emotions:

Eighteen students indicated happiness, 4 distrust and 6 indicated tranquility. The students who selected happiness added the following points: "They are expensive solutions but they allow health care," "It is important to have technology that helps us to tackle the problem at home. The problem is that not all the people have access to it," "It makes me happy to know that there is a solution to the problem." The comments of the students who indicated distrust were "not all filters allow the removal of arsenic," "It causes me concern and distrust because there are many people who trust these technologies and are unaware of how they work," "Not all the people can have access to these technologies. It is an unequal way to solve the problem."

In relation to Supplementary material (Image 2) on the skin lesions caused by the chronic consumption of arsenic in water, 20 students indicated sadness and fear, 18 selected anger and 13 indicated indignation. The comments were the following: "This type of disease generates fear and concern since it is very serious," "It is sad to know that there are people who do not have access to drinking water," "It is the effect that ignorance can cause on a certain environmental problem," "It generates fear not knowing what a person is consuming," "It is sad to know that people get sick due to the lack of knowledge on the subject and scarcity of resources to be able to have drinking water," "Lack of concern of the government."

On the other hand, in relation to Supplementary material (Image 3) on the situation in the Province of Buenos Aires, and 4, on sustainable technology, all the students selected the same emotions, which was a very striking fact.

In relation to Supplementary material (Image 3), they selected sadness, fear and indignation. Among their responses, some students said "it makes me indignant due to the amount of effects that this situation can have for the purification of the water we consume," "I am afraid to know that this could be more serious in the future and there are not many people with the initiative to solve it," "I do not know exactly how to describe what the image makes me feel since it shows me that we are in a very bad place in the world because the governments do nothing," "It causes me concern and fear for my family who does not know about the issues of water," "It makes me sad and concerned to see how it is such a big problem and the population does not know about the issue and ignores it."

For Supplementary material (Image 4), they selected happiness, tranquility and expressed the following opinions: "This type of technology gives me happiness and tranquility because the people who need it the most will be helped," "It drives me to continue studying and acquire a commitment to solve the problem.," "I am glad that there are solutions although these problems should not exist," "It makes me happy that Public Universities develop technologies to be able to solve society's problems," "I am afraid of knowing what is happening in the world but this allows me to face problems as they are."

Finally, when inquiring openly about the perception of the solution to the problem, the students expressed the following points:

1. "I would like to contribute with more water analysis in Tandil that can help the investigation of this topic."
2. "I could investigate more on the subject and make my acquaintances aware of the issue by looking for new materials for the removal of arsenic."

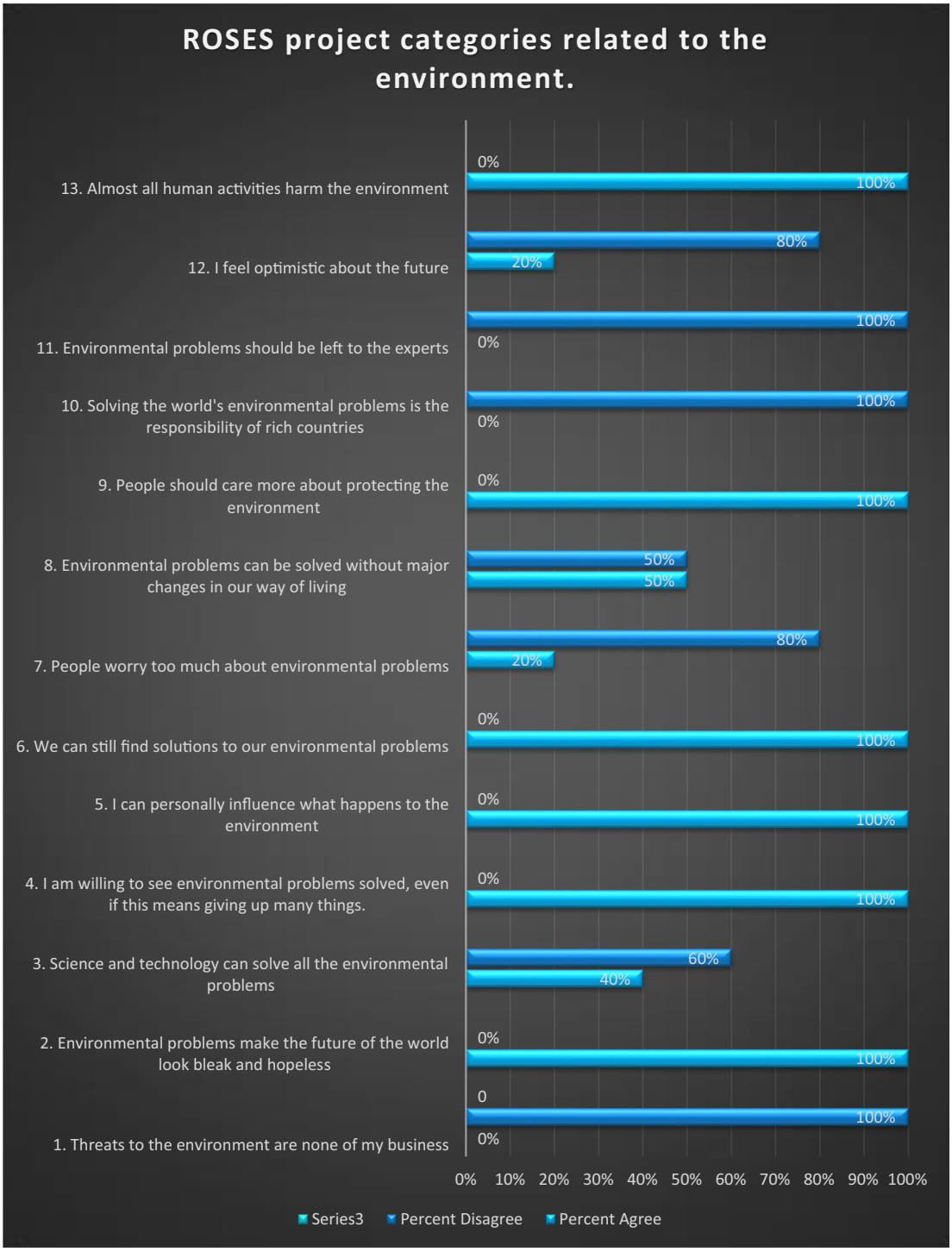


FIGURE 2
Result of the ROSES project categories related to the environment.

3. "I would like to be able to learn more about the problem in order to disseminate the issue to my acquaintances."
4. "I think it is important to raise awareness of this issue, there are more people."
5. "I would try to prevent all those human activities that cause this type of problem, such as mining, through chemical education."
6. "To solve this problem, first the destruction of wetlands would have to be reduced and, second, in terms of filtration equipment, a greater investment by the State should be generated."
7. "It is necessary to generate educational actions so that the population can know what is happening since many people think that boiling water can eliminate arsenic."

TABLE 2 Categories related to arsenic in water.

| Categories related to arsenic in water | Percent agree | Percent disagree |
|---|---|---|
| Arsenic in water is an environmental problem | 50% | 50% |
| 15. Arsenic in water affects the area where I live | 0% | 100% |
| 16. The State deals with the situation of arsenic in water | 0% | 100% |
| 17. A greater approach to the issue of arsenic in water in schools is needed to raise awareness about the issue | 100% | 0% |
| 18. The problem of arsenic in water limits the fulfillment of Human Rights | 100% | 0% |

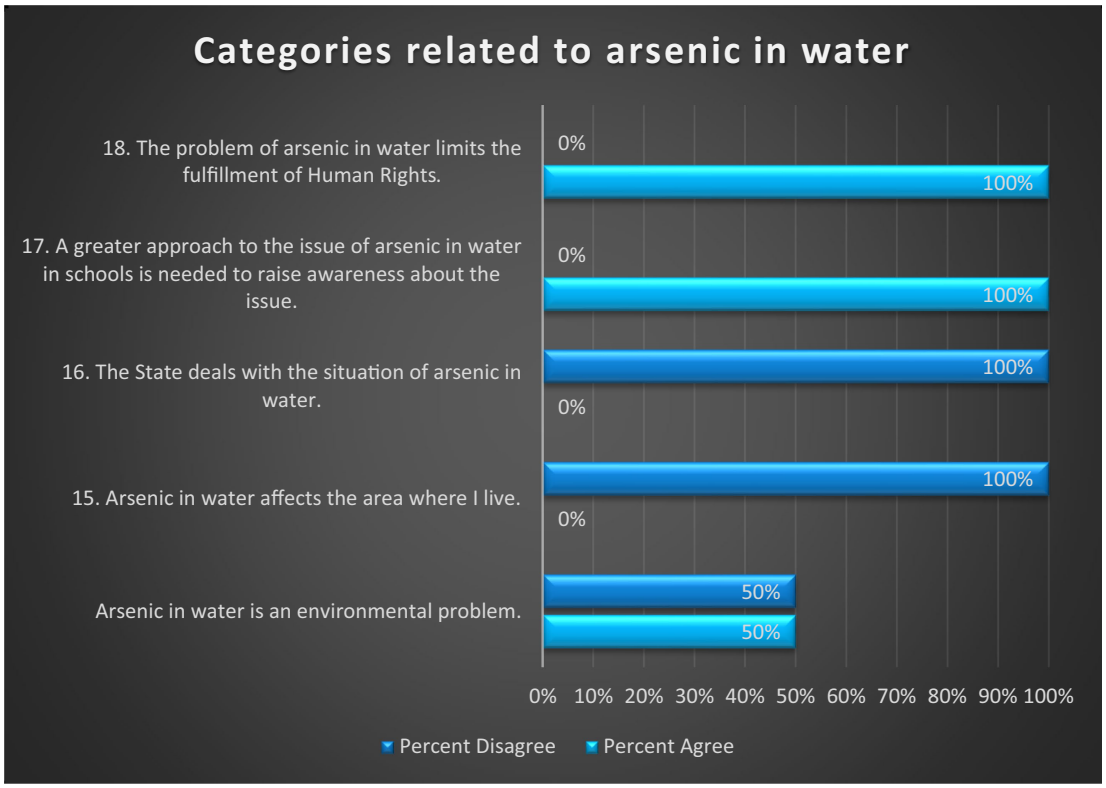


FIGURE 3
Results of the categories related to arsenic in water.

8. "I would be very interested to know more about the subject to be able to make a person transmit the information."
9. "We are not able to develop technologies to generate global actions, but we can communicate to people so that they know about the subject in a scientific way and with an appropriate language."
10. "We spend a lot of time on social networks and we could generate different dissemination materials on the topic."
11. "It is important for us to make other people become aware of the issue as well as we did with this talk from The Quilmes University thanks to the investigator Damian Lampert."
12. "We need to help people."
13. "We could manufacture more technologies and bring them closer to different parts of the country."
14. "First we must understand the theme. I do not understand how these environmental problems are not being addressed in all subjects."
15. "We have the knowledge and that must be transmitted."
16. "We can show the topic at the science fair."
17. "You have to raise awareness."
18. "We have to show what happens through laboratory analysis."
19. "We must talk on the radio and television so that we can all find solutions together."
20. "I can contribute by being grateful for having received the training to know about the subject."

This type of results allows us to highlight the role of EE in strengthening participation politics and activism so that this future really changes and is not just a immutable and irreversible destiny.

## 4.1 Analysis of the results and presentation of social representations on the problem of arsenic in water

As mentioned on the introduction, social representations encompass three aspects: information and knowledge, attitude and emotion. From the methodological triangulation of these aspects and

the results obtained from the ROSES surveys, the open questions and the analysis of the images, it is possible to determine the existing social representations.

In relation to knowledge and information, the student body was aware of As in water as an environmental problem, but only 50% indicated that it affected Argentina. On the other hand, any of the students was able to determine the origin of the contaminant in water. Also, the situation in the town in which they live was unknown. It can be determined that for the students As in water is associated with an environmental problem, but they do not present knowledge about its origin and its occurrence in the country and in the locality where they live.

In relation to attitudes, the students expressed their interest in modifying environmental issues based on their actions and the intervention of the State and scientific research. At all times an androcentric image of the environmental problems is presented in which the students themselves recognize that they cause environmental problems. However, they are willing to give up different aspects of their life in order to solve them. On the other hand, they recognize the access to drinking water as a Human Right and that the presence of As violates that right. Likewise, in multiple results (either from the ROSES questionnaire or from the images and the open questions) they point out the importance of education and awareness. Some students recognize their lack of knowledge on the subject and the importance of knowing about it. They even mention practices that people carry out to try to eliminate arsenic. In their active role to solve the problem, 80% of the students propose to spread the problem and generate opportunities for other people to know about the subject.

On the other hand, in relation to emotion, different feelings are presented in relation to the theme: when learning about the situation in the Province of Buenos Aires and the effects of As on health, fear, sadness and impotence are presented. Above all, this last emotion is related to the poor ability to solve the problem. In relation to conventional technologies to remove contaminants in homes, it generates happiness, but at the same time uncertainty because a few people know exactly how the filters work. What has generated happiness and joy are sustainable technologies. This is because the students recognize that this type of development carried out by universities can reach the entire population and not only the people who have the money to buy a filter.

In conclusion, we can identify that there is a lack of knowledge on the problem itself, but the students 'attitudes and interests are to be able to solve it (once they knew what it was about). The current situation generates fear, concern and uncertainty, but at the same time, happiness and joy when they recognise the practices that are developed within the universities. Although these were the emotions analyzed, based on the results of the ROSES Project, an interest can be found in the development of environmental practices and attitudes. In the development of the didactic unit will be reflected if it is true that the students show that interest and way of acting towards environmental issues.

## 4.2 The challenge of STS education

STS education should not be immune to these results. It is important to become aware of these problems and not generate fear and uncertainty in students. Likewise, they must work from the global vision of One health so that they can reaffirm their attitude towards the environment and that everyone is interconnected.

In the conclusions of the final report of the CONICET Red de Seguridad Alimentaria (2018), the following guidelines are established to address the problem of As in water:

1. Information, since the problem is unknown by a broad stratum of the society.
2. Sensitise the community (without causing panic).
3. Investigate and develop economical treatment technologies.

Without going any further, the items in which this report culminates coincide with the students' attitudes and interests, so STS practices should be developed in order to make the subject be able to be addressed in classrooms. This item is included in the curricular designs, for instance, in the subject Environment, Development and Society from 6th year of secondary school, and it poses the following case of study:

> "The study of pollutants of anthropic origin (expressed, for example, in the contamination of the Matanza-Riachuelo basin and underground courses such as the Pampa and el Puelche) and natural toxins such as arsenic, which is of great importance in Argentina and the province of Buenos Aires expressed in the frequency in which the chronic regional endemic hydroarsenism disease (CREH) appears in the population."

Water constitutes an essential human right of a universal nature, the satisfaction of which is essential for the adequate exercise of other rights associated with the realization of the most urgent basic needs in the region (Condolucci et al., 2020). For this reason, a didactic unit (DU) was developed in order to work on the contextualized problem, from the STS approach. In this way, questions that are far from simple are included in the DU, linked to the reason for the magnitude of the levels of social inequality, in relation to access and quality of water, in society in order to generate the introduction to food safety.

The DU was presented in five moments: in the first, a presentation was made on the understanding of the social dimension of Human Rights and its diffuse normative field. In the second moment, the organizations in charge of food control were presented: National Agri-Food Health and Quality Service and the National Food Institute. To then present the importance of the role of the State in ensuring food safety. The third moment aspects related to environmental activism were presented so that the students had to solve this slogan "How can we solve the environmental problem through the social movement?" This activity was carried out through an open analysis, debate style, where the following points emerged: development of technologies, highlighting the roles of the State and the municipality, carrying out judicial actions in appropriate organizations and developing awareness campaigns about water as a human right. As a result of this activity, posters, advertisements and multimedia tools were made. The fourth activity incorporated a technological section and an artistic activity, in accordance with the STS approach to teaching. Firstly, students were asked to investigate the water purification process in Buenos Aires. In this way, the students had to identify which was the process or unit operation in which the elimination or reduction of As in the water was guaranteed. Based on this investigation, the following questions were presented:

What is the situation in Tandil regarding the water purification process?

What is the role of the State in ensuring the purification of water?

From this, a debate was held on the human right of access to drinking water. On the other hand, returning to the concept of "One health," the students had to create an image in which they show the effects of As on the health of plants, animals, the ecosystem and humans. In this way, the aim was to incorporate the concept of health by allowing students to identify that As can enter the body from foods that were produced with contaminated water.

As the students who participated in this research present an orientation for high school chemistry, we proceeded to design a didactic sequence that incorporates interests, attitudes and emotions on the subject. For this reason, the fifth activity was developed to make the arsenic map of Tandil. In this way, the students were informed of the methodology for taking samples and, in a common class, a colorimetric analysis was carried out in order to determine the approximate levels of arsenic in water.

Based on the results obtained, the following map was prepared (Figure 4):

For the development of the map, the categories presented by the CONICET Food Safety Network in which Rank 1 (R1) refers to less than 10 μg/L (represented in green and complying with the Argentine Food Code), Rank 2, 3 and 4 (R2, R3, R4) do not comply with the Argentine Food Code and are represented with the colors yellow (between 1–50 μg/L), orange (between 50–350 μg/L) and red (between 350–500 μg/L) respectively were used. In the case of the elaborated map, there is no sample in Tandil that is represented in red. Finally, from the made map, it was possible to work out the origin of arsenic in the city from the biographical review of other investigations (Barranquero et al., 2012).

In this way, a contextualized didactic sequence was carried out in the students' locality, in which they were able to face their own emotions and learn more about the subject.

## 5 Final reflections

This research allows us to understand the importance of knowing the social representations in the development of educational proposals. Teachers often stop only to know a part of the social representations: information and knowledge. However, it is essential to know the attitudes, interests and emotions. In environmental education, the issues must be worked on in a contextualized way without generating fear in the students, but, acquiring their commitment and interest.

In this case, work was done on the problem of arsenic in water, but it does not prevent this methodology from being used for different local situations.

On the other hand, in relation to STS education, it is often attacked by different professionals, as Porro (2022) has indicated, but we cannot fail to recognize that it allows contextualizing teaching in the interest and feelings of students in order to form a critical citizenship in matters of Human Rights.

It is worth noting that the development of STS proposals in relation to social representations about arsenic in water had already been carried out within our research group (Condolucci

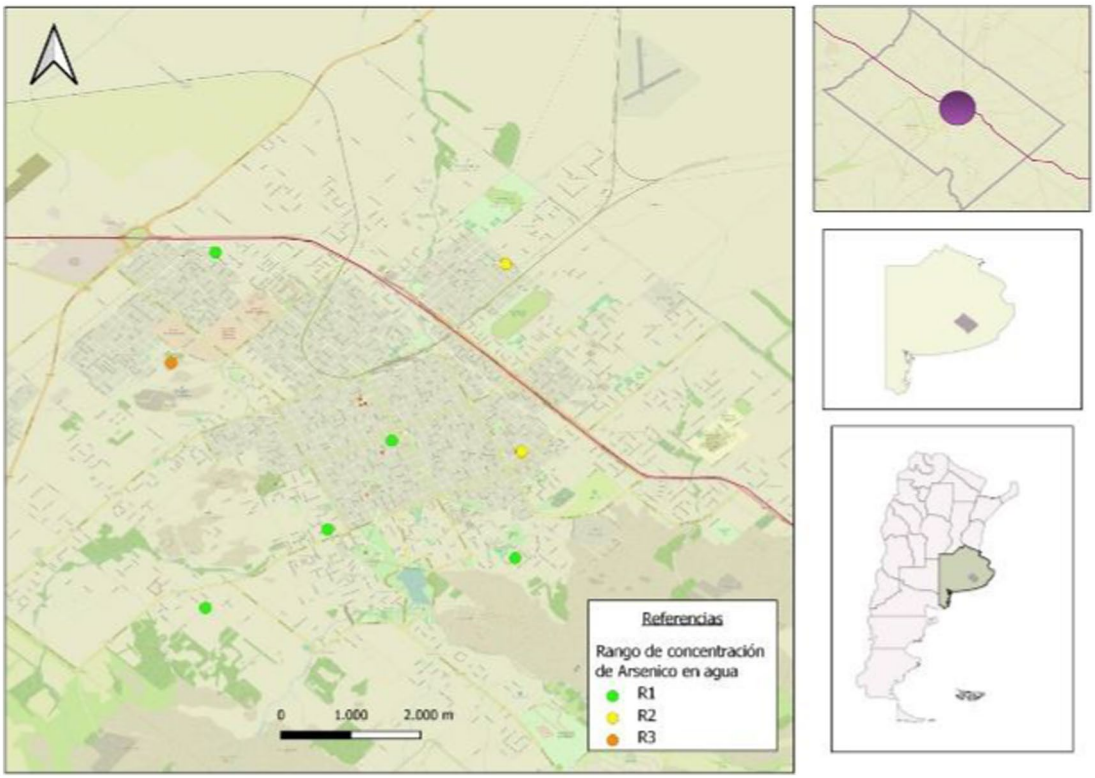


FIGURE 4
Arsenic in water in Tandil.

et al., 2020; Lampert and Porro, 2020; Lampert et al., 2021). However, only information, knowledge, interests and attitudes had been taken into account, not emotions. For this reason, for this particular case, these educational practices have been adapted, including the results of emotions: the fear generated by the map of the Province of Buenos Aires and the joy of being able to collaborate with the situation.

## Data availability statement

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

## Author contributions

DL: Writing – original draft, Writing – review & editing. SP: Writing – review & editing.

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## Conflict of interest

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## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1305788/full#supplementary-material

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