Contamination of water resources as a starting point for socio-scientific activism.

Abstract:
Science curricula emphasize the need to involve students in civil society issues related to science, highlighting the primacy of learning about the science-technology-society-environment relationship. The objective of this work is to know the students' learning when they get involved in the attempt to solve the problem related to the pollution of the stream near their school. The research methodology is qualitative, interpretative and based on participant observation. Twenty-one students from two 8th grade classes[1] with an alternative curriculum, living in a rural environment in southwestern Portugal, participated in the study. Data were collected through the teacher's diary, written documents and interviews with the students (conducted at the final of the study). The results reveal that the positive experiences provided by the radio club gave them confidence and encouraged them to engage in community activism related to the pollution of the local stream. This activism takes the form of a puppet show about sewage treatment. Also, the results show us that activism leads students to the identification of the science and technology issues that are at the root of the pollution of the creek, expanding their knowledge about the problem and discussing different perspectives for its solution. In addition, young people recognize that knowledge enables them to inform other members of the community and realize that they have the right to become involved in socio-scientific issues that affect their quality of life.
Keywords: Socio-scientific issues, Socio-environmental issues in the classroom, Scientific literacy, Science education.

Introduction

Science and technology have a great impact on ecosystems and on the quality of life of populations. However, communities do not always have an active and effective participation in the discussion and decision-making on issues related to science and technology. This problematic exposes the need to democratize sciences, that is, to include in the public debate a more plural, relational and dialogic knowledge about socio-scientific issues (Colucci-Gray and Camino, 2014). In fact, Little (2009) evidences that it is necessary to connect local communities, in a more effective way, with state authorities that assess environmental toxicity risks. According to this author, the community possesses knowledge that is not always taken into equal consideration as the scientists' perspective, so it is necessary to build more democratic alliances with the affected communities. This democratic deficit in decision-making on socio-scientific issues is well exposed by Goldstein (2017). In her study on the problematic of the Angra dos Reis nuclear power plant, Brazil, the author explains to us that local communities are not heard and are not properly informed about the consequences of the project. According to the author, the situation is even more worrying when it is verified that the populations do not have a clear idea of how to act in the event of a catastrophe. These issues, both locally and globally, have had a strong influence on science curricula, and the importance of science education in students' decision making on socio-scientific issues (CSC) (Aikenhead, 2010; NRC, 2010; NGSS, 2013; Osborne and Dillon, 2008) and in individual and civic responsibility for them (NAAEE, 2004) is currently recognized.

Science teaching from CSC raises students' interest in science (Freire, Faria, Galvão, & Reis, 2013; Simon and Amos, 2011) and the learning of scientific concepts in different areas, for example, in Genetics (Puig and Jiménez-Aleixandre, 2011), in Biology (Dawson, 2011), in Environmental Science (Evagorou, 2011), in Chemistry

(Sadler, Klosterman, and Topcu, 2011) and in the Nature of Science (Apotheker, Blonder, Akaygun, Reis, Kampschulte, and Laherto, 2017; Reis and Galvão, 2004; Zeidler, Applebaum, and Sadler, 2011). Likewise, other authors let us know that students, when involved in CSCs, expand their knowledge about science ethics and become more sensitive to these issues (Eastwood, Schlegel, & Cook, 2011). Some of these issues divide society by the fact that there are explanations and solutions based on moral principles that are not always reconcilable (Stradling, 1985). Considering the nature and transcendence of these issues due to their high impact on ecosystems and the lack of consensus on solutions (e.g., Stawkowski, 2016), their discussion in class leads to different interpretations of the facts by teachers and students (Oulton, Dillon, & Grace, 2004). For this reason, Science Education from socio-scientific controversy challenges teachers, but also fosters their professional development. For example, the initial distrust detected in Simon and Amos (2011) about teaching science from CSCs is overcome at the end of the study. Similarly, Wong, Zeidler and Klosterman (2011) show some difficulty in planning lessons based on CSCs, but progressively gain autonomy and end up revealing enthusiasm in doing so. Some teachers fear that students will not respond well, however, in the end, they are pleasantly surprised by their performance and are willing to implement this teaching strategy (Zeidler, Bell, Sadler, & Eastwood, 2011). In fact, the involvement of teachers in socio-scientific activism practice groups, creating materials together, sharing and learning with experiences, constitutes a form of mutual support in overcoming obstacles (Linhares and Reis, 2014; Reis, 2014a, b). It is understood as socio-scientific activism, the democratic participation of students with the aim of trying to solve CSCs and mitigate the associated tensions (Alsop and Bencze, 2014; Baptista, Reis and Andrade, 2018). An important aspect in the training of students on socio-scientific activism is the involvement of the community, once it is intended to broaden the discussion of these issues beyond the classroom and school space (Hodson, 2011; Reis, 2013). Fostering socio-scientific activism in the school context is fundamental for students to be full citizens, which is an essential dimension of scientific literacy (Gray, Colucci-Gray, & Camino, 2009; Kolst0, 2001; Marques & Reis, 2017; Millar & Hunt, 2002; Reis, 2014a, b).

Based on these premises, this paper explores socio-scientific activism with 8th grade students (between 13 and 15 years old). More specifically, the aim is to know the students' learning when they get involved in the attempt to solve the problem related to the pollution of the stream near their school. This study has been developed within the scope of the We Act Project - Promoting Collective Activism on Socio-Scientific Issues (Reis, 2014a, b).

The socio-scientific issue

Very close to the school there is a stream where domestic effluents are discharged without proper treatment. As a result, the stream is polluted and smells bad, so the environmental problem is evident. This situation is aggravated when it does not rain. The community is aware of the situation and, naturally, they show their discomfort. The neighbors complain about the bad smell in their houses that comes from the pipe that carries the effluents to the creek. The problem, besides being old, is political. In fact, the City Council has promised, in several election campaigns, to solve the problem by installing a sewage station. However, the creek continues to be a source of environmental pollution and a risk to public health. Thus, this issue is considered to have potential to involve students in socio-scientific activism (Alsop and Bencze, 2014).

Methodology

Participants

Twenty-one 8th grade students between the ages of 13 and 15 participated in this study. The students belonged to two classes with an alternative curriculum -developed specifically for these students with specific learning needs- with areas such as horticulture, cooking and information and communication technologies. These young people showed no interest in school subjects, had no study habits, poor behavior and came from a disadvantaged rural background.

Method of data collection

This research is qualitative in nature (Erickson, 1986), according to the naturalistic paradigm (Bogdan and Biklen, 1994), which has been developed during a school year. The data were collected using the participant observation method. The researcher (and science teacher) participated in the students' learning process, taking notes in all classes. The data were supplemented by focus group type interviews — conducted with the students at the end of the research. The interviews focused on the dimensions: students' liking/interest, students' difficulties and learning, perceptions about science classes, activism. In addition, students performed eight tasks during science classes, the results of which were analyzed for the research. These tasks were designed by the authors according to Bybee's (1997) 5E model. This model is based on a constructivist perspective of learning and contemplates five phases: Envelop, Explore, Explain, Elaborate, and Evaluate. In the involvement phase, the aim is to capture the students' interest and curiosity in the investigation of a problem. In the explore phase, aimed at finding solutions to the problem, students posed and tested hypotheses. As a group, they discussed the results with their peers and organized the information to communicate it to the class. In the explanation phase, they responded to the problem, articulating what they observed with the explanatory hypotheses and their verification. In this phase, students were invited to communicate the solution to the problem in class, using scientific language and relying on the evidence collected. In the elaboration phase, students applied what they learned in the task to other contexts, developing competencies and expanding their knowledge. Finally, in the evaluation phase, students reflected on the work developed, evaluating the task and what they learned (Bybee, 1997). In this research, eight different tasks were carried out: The pollution of the stream; The water cycle; The water we use in the kitchen; Wastewater; Sustainable water management; Sustainable agriculture; Biodegradable waste cycle (from the garden to the table and from the table to the garden); and, It was once upon a time (the students told their experiences around water pollution of the stream and thought about how to disseminate them). These tasks were intended to enable students to (i) understand the sources of water resource pollution and (ii) take action focused on solving the specific problem of stream pollution (Hodson 2011; Reis 2013).

Structure and description of the activity

Socio-scientific activism, in this research, was developed in five stages, according to Eilks' model (Sadler, Romine, & Topçu, 2016):

- First stage. Identification of the problem and capturing the interest of the students. The activity is a field trip to the stream.
- Second stage. Construction of the scientific knowledge necessary to understand the problem and propose solutions. The activities consisted of a search for information on the operation of the drinking water treatment plant (WWTP) and the wastewater treatment plant (WWTP) and the preparation of a questionnaire for WWTP and WWTP technicians during a study visit.
- Third stage. Identification of solutions, analyzing divergent ways of implementing the solution in order to seek consensus. The students perceived the tensions related to the pollution of the stream through informal talks with the population and with a role play activity they carried out in class. In this activity the students represented different characters with different interests related to the solution of the pollution problem, so that a discussion of divergent ideas and the attempt to find consensus became possible. At the end, they wrote a manifesto about the discussion generated in class.
- Fourth stage. Socio-scientific activism. The students carried out activities related to the pollution of the creek. One of these activities was the creation of a radio club at the school. The young people visited a radio station

where they interviewed the technicians to understand how it works, with questions prepared by them. They then created the radio's operating rules and committed themselves to following them, with the support of the teachers and with the knowledge of the management. The radio operated during recess with the presence of the teachers. At the same time, the students worked on activism about the pollution of the creek, with the creation of a puppet theater for the community.

- Fifth step, a balance of the activity was made, with special attention to the lessons learned, the difficulties encountered and what pleased the students more or less.

Results

First stage. During the field trip, the students noticed the existence of a conduit open to the creek and observed the conditions in which it was found. For example, one of the students commented: In the stream the water is polluted because of the sewage, the water smells bad, it is dirty and [has] dead fish (written record, homework). The example shows that students are sensitive to the signs of pollution in the creek. In fact, the observations evidence a possible deficit of dissolved oxygen in the water and ineffective wastewater treatment. Then, in class, wastewater treatment was addressed and the students were interested, spontaneously intervening in the discussion. A note in the teacher's diary: Luisa said [in class] that in the village where she lives there is a WWTP that does not work. The students discuss among themselves about the quality of the water (streams, rivers) in the places where they live. Indeed, after the field trip, the students' interest in an everyday issue made it possible to have a class discussion with a lot of participation on science curricular topics. Also, during the class, the topic of water treatment for human consumption came up and the students revealed a superficial knowledge of the subject. For example, regarding water for human consumption, Sebastião commented: The shepherd drinks water from puddles, folds a cloth several times and then sucks the water. He did it once for my father to see and he filled a bottle and it was clean (teacher's diary). Indeed, the student did not seem to know that drinking water has to be bacteriologically controlled and that there are specific treatments. The questions from classmates support this idea, as Noel asked: Why can't you drink dirty water (written record) and Ana wanted to know: How do you clean the water (written record, homework). The questions asked by the students are appropriate and reveal their interest and desire to expand their knowledge on the topic of drinking water treatment. Therefore, the teacher decided, in addition, to make a study visit to the drinking water treatment plant (ETA). Regarding the exploration of the topic of stream pollution, the students developed interview scripts with the ETAR and ETA technicians, based on the research done in class. These activities provided students with opportunities to identify science topics related to the stream pollution problem. For example, one group of students asked: How can sewer water be treated? How does a WWTP work? Why does sewer water drain into the creek? (written record, homework). In this example, the curiosity of the young people about topics in their curriculum that are related to the problem of pollution in the creek is evident. In addition, regarding ETA, another group asked: What does water do to us when it is spoiled? What are the products to make water clean and treated? Which is better for clean water, chlorine or ozone? Which is cheaper chlorine or ozone? (written record, homework). In fact, these questions are relevant in the daily life of the students and the community. Moreover, they are very relevant in the context of the subject of Physical and Natural Sciences. As a result of all this curiosity, the students showed great interest in learning about the functioning of the ETA and the ETAR. After the elaboration of the scripts and all the formalities related to the visit were solved, the visit was carried out starting at the ETA, which is located next to a large lagoon, and ending at the ETAR.

Second stage. During the guided visit, the young people interviewed the technicians and observed everything, which helped them to broaden their knowledge in this regard. In this regard, one group wrote: I learned how the water reaches our homes, which is like this, first the gentlemen get the water to reach their factory[s] and then they clean it, treat it and then the water comes to our house[s] (written record, homework). As a whole, the students showed a broadening of their knowledge about the path of drinking water, from the time it is collected in the lagoon, through treatment at the station, to the homes. This topic, although parallel to the central theme, is related and important for a broader understanding of the problem under study. In order for the students to understand the origin of the pollution of the stream and discuss possible solutions, the visit to the ETAR was especially relevant. The data show that the students recognize the progression of their learning. For example, one of the groups commented: I learned how [drinking] water and [sewage] water is treated. We learned how water is treated and where the sewer water goes (written record, homework). It is evident that the students acquired learning that is relevant to the understanding of the problem in question, particularly about the treatment of wastewater and its final destination. It is precisely this knowledge that will allow them to go further and understand that the problem of stream pollution can be solved through adequate treatment.

Third stage. After the visit, the class returned to the discussion on the problem of pollution.

A group of students clearly identified the situation by commenting: Wastewater is not treated and goes to the creek (...) wastewater is the water that comes from the neighbors' houses and goes to the creek (written record, homework). Thus, the students expressed themselves adequately about the creek, revealing important disciplinary learning and a clear vision about the topic. Next, they discussed the location of a hypothetical ETAR in a role play task in which they represented characters with different interests and proposals. In relation to this, some groups commented:

Group 1- "The interest of the population of the XX neighborhood is that the ETAR should be built in another place [not next to the creek]. In the neighborhood they want to build [on that site] a green park."

Group 2 - "The interest of the bird [protection] group is to defend nature" (written record, homework).

Another group added:

"Group 3 defended the GP company. It is more convenient for them the ETAR next to the creek, once they projected an urbanization on the land [destined] for the [construction] of the ETAR. Group 4 defended company YY. It is in their interest to build the ETAR near the creek, because if not, they do not receive compensation from the GP company" (written record, homework).

In fact, this activity, in which students discussed different perspectives, gave them a glimpse of what might lie behind science- and technology-based issues related to community well-being, acquiring a deeper and more real knowledge about CSCs. In addition, they developed a perspective of their own. This became visible, for example, in the focus group interview:

Teacher: In what situation have you been encouraged to defend an opinion?

João - [in the task] of the ETAR.

Anne: [We wanted] a garden next to the creek, people want to walk there and they can't because it smells bad.

Indeed, the discussion on the problem of stream pollution allowed the students to make their ideas known and defend them. In addition, the confrontation of different perspectives represented an opportunity to look for good arguments to support their positions and to recognize the duties and rights of a citizen. In the evaluation of the role play activity, the students commented: We learn to disclose and defend our rights. We learn to debate our interests. How to protect our things (written record, homework). The student-citizens, by recognizing that they have rights in public issues - as in the case of sewage treatment - and that these science-related issues sometimes rub shoulders with outside interests, reveal important learning in the domain of socio-scientific activism. Likewise, they value the knowledge that allows them to defend these rights. Thus, when the students were asked in the interview how they acquired the power to influence other people's decisions on socio-scientific issues, Nelson answered: Because we learn and teach others. Rogério corroborated by saying: So if we know things and the person we are talking to has a contrary opinion, we tell him what we know and then he will think about the subject, if it is true, if not, he will continue with his own (focus group interview).

In sum, the involvement of the students in socio-scientific activism on the problem of pollution of the stream surrounding the school led them to learn that wastewater must be treated and that this is not done in the waters of the conduit that drains into the stream. It also allowed them to discuss possible solutions to the problem and to recognize that these solutions may affect the interests of others. In addition, they recognized that they have rights "as members of the community" in the discussion of science and technology-based public issues and realized that knowledge allows them to influence the opinions of other citizens on socio-scientific controversies.

Fourth stage. In this stage, the young people created the puppets and wrote the theater script. An excerpt from the script is transcribed below and a moment from the theater is illustrated (Figure 1).

Sebastião: So an ETA is just this?

Sara: Just barely, Sebastião, do you think that treating the water coming from our house is an easy task?

Margarida: Of course it is not, because water goes through severalf^ses in this whole process.

Carla: What is the difference between an IETA and an ETAR, Professor Teresa?

Teacher: Then we go to the ETAR and from the guided tour, you yourself are going to explain the difference. Is that possible?

Carla: Yes! Yes! Teacher: Sure!

Noel: So, shall we go to the ETAR?

María in "voice-over": Already in the ETAR.

Teacher: Look, look, guys! Here we are.

Sebastião: Chiii! How coolᵗ r!

Fernando: this is not foot odor. It is much worse!

Carla: I understood the difference between an ETA and an ETAR! I'm going right now to explain everything to teacher Teresa.

Noel: Look, he's sucking up to the teacher^ Is it so hard to understand that an ETA treats the water before it gets to our homes and the ETAR treats it after it leaves our homes!

Fernando: Not only from our homes, smarty pants!

Figure 1
Puppet theater.

In fact, the socio-scientific activism carried out by the students on the problem of the local stream, discussing at length the science and technology issues at the root of the problem and the possible solutions, as well as the associated individual, collective and political responsibilities, led the young people to take action outside the classroom. This initiative by the students took place at the school and was intended to broaden their knowledge, both of their curriculum and of the domain of socio-scientific activism, and to bring them closer to the whole community.

On the other hand, the creation and dynamization of a radio club led the students to interact with the community through a set of diverse activities, some of which were related to their professional vocation. For example, during the study visit to the local radio station, the young people participated in a live program, as can be seen in Figure 2 below.

Figure 2
Radio studio visit

Activities such as these, in which students had the opportunity to see members of the community performing the professions they love, encouraged them to participate in the radio program and led them to see themselves as citizens. The positive aspect of this experience helped them gain confidence and interest in school activities. Back at school, the young people were eager to start a radio club. To this end, they undertook a number of activities that were important for their involvement in school activities, particularly in stream pollution activism. For example, to run the club, the students created an operating schedule and a programming template. The creation of the schedule required the organization of the students, according to their free time and the availability of teachers, and the assumption of responsibility for working at recess.

In addition, the development of the programming template required a great deal of effort on the part of the students: with what they learned at the radio station, they did a search on the topics that could be included in the programming and constructed the format of the programs. Annex 1 shows the programming template developed by the young people.

The staff presents a wide variety of programs, both informative and entertaining. Of the topics presented, the program Canciones pedidas (Songs requested) was very successful. In it, the audience could choose songs and dedicate them to someone. For this purpose, requests were received at the station at a certain time and then broadcasted.

In this way, the students provided a service to the entire school, assuming responsibilities as active citizens. The radio club had a great impact on the school, as it enlivened recess. Leading this project provided moments of success and made them gain confidence and interest to get involved in activism.

Fifth stage. The students made a balance of the activities they carried out. Regarding what they liked learning, for example, they answered "I liked knowing what an ETA and an ETAR are", "I liked knowing how all the water is treated", "I liked knowing where the water from our houses comes from and where it goes", "What I liked most was seeing the ETA and what I liked least was the smell of the sewage treatment plant" (written record, homework). These examples show well that the students were interested in investigating the socio-scientific issue and that they liked learning related disciplinary content. This is corroborated by mentioning what they would like to learn more about. For example, "I would like to know all about riverbanks", "I would like to know how dams are built", "I wonder where the bad smell of polluted water comes from" (written record, homework). In fact, the students liked to delve deeper into the problem of stream pollution and showed interest in learning more about this issue.

Conclusions

Socio-scientific activism on an environmental issue related to the students made it possible for them to become interested in science and learn science. These results are in agreement with other studies that also show that students learn science when they are involved in socio-scientific activism (Alsop & Bencze, 2014; Baptista, Reis, & Andrade, 2018; Blatt, 2013; Marques & Reis, 2017). Moreover, it allowed students to get involved in the public issues of Science, make decisions and develop their individual and civic responsibility, as advised in international documents on Science Education (NAAEE, 2004). Also, by engaging in socio-scientific activism, especially when it involves the community, students learn to see themselves as members of the community, with duties and rights, as advocated by other authors (Colucci-Gray and Camino, 2014). Moreover, they showed an example of what scientific literacy is (Gray et al., 2009; Hodson, 2011). In fact, they investigated a problem in their community, understood it in the light of scientific knowledge, and acted in the school space through a puppet theater, suggesting a solution to the problem. Another nuance of socio-scientific activism that should be emphasized is the fact that students learned science from concrete situations with social impact, discussing their tensions and subjectivity and the associated scientific processes. It is precisely this learning that some authors refer to as essential for students to be able to intervene in an informed way in science and technology issues (Driver, Leach, Millar, and Scott, 1996; Schwartz, Lederman, and Crawford, 2004). Thus, socioscientific activism, as developed in this research, entailed an improvement in students' engagement for science learning and for their empowerment towards a more participatory, enlightened, and informed citizenship (Hodson, 2011; Reis, 2014a,b). Moreover, in this research, students practiced socio-scientific activism beyond the classroom: organizing a community-wide puppet theater to draw attention to water treatment. The message intended to be conveyed by this initiative was that the issue of stream pollution was a socio-scientific but also a political issue that created many tensions in the local community. The school was not intended to intensify the tension but to help defuse it. Therefore, one way to sensitize the members of the City Council to the urgency of solving the problem was through the performance of the play that presented a solution, i.e., water treatment, in general. In this research, several factors contributed to the success of the socio-scientific activism on the pollution of the creek: the relevance of the issue in the lives of the students, the active participation of the students in their learning, the valuing of their ideas in the discussion, and the confidence that resulted from their empowerment to discuss socio-scientific issues. The radio club helped the students to involve the community in activism, and also provided them with enriching experiences, allowing them to gain recognition from their peers and the rest of the community. Progressively, they have been increasingly valuing school issues and involving the community in activism. Socio-scientific activism should be an exercise of citizenship on public issues with a scientific and technological base and should serve to encourage students to act democratically and in a reasoned manner on science issues with an impact on their lives and on the life of the community, as has been encouraged in this research.

Supplementary material

Annex 1 (pdf)

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Notes

[1] In the Spanish Education System it is equivalent to the 2nd year of ESO.

Additional information

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