

Chemistry Teaching in a STSE Perspective: A School Project

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Abstract This study focuses on environmental education in school, based on a work project with a laboratorial component. Thus, it is intended to disclose part of a wider research on the evaluation of an intervention project in the local environment, developed by students of a secondary school in the north of Portugal. The research is qualitative in nature, and it is focused on the discursive textual analysis of the report made by the coordinator of a school project and in the reports of students. The results show more awareness by young people, despite some difficulties in scientific writing and dissemination of results. Overall, there is a positive assessment of the project, the deepening of students' scientific literacy and their commitment to a sustainable development of the local environment.

Keywords: *environmental education, scientific literacy, chemistry teaching, school project*

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1. Introduction

In the twenty-first century, the teaching of Science cannot be materialized in a compartmentalized learning with content of reality, with no obvious relationship to natural phenomena. On the contrary, the relevance of scientific knowledge requires young people to be able to participate in scientific discussions and to be actively involved in the current issues of science and technology [1]. In this sense, the curriculum reform of science teaching, which began in the late twentieth century, promoted the scientific literacy of students, in a STSE perspective (Science, Technology, Society and Environment), for environmental education for sustainability [2]. This is a democratic-oriented education, which has been reinforced by international organizations [3]. One way to achieve a high quality education is by promoting teaching methods and active learning, linked to action and reflection inherent to development projects. The ability to design, develop and participate in projects is undoubtedly a relevant capacity to be acquired by young people [4].

In this context, it is interesting to evaluate the work in the field of action of a project of environmental intervention, with a laboratorial component [5,6]. The project, entitled "Our Water", developed by high school students of Chemistry, aims to further develop the scientific literacy of young people and to improve educational quality.

One of the reasons that led to the water theme selection was, in addition to the emphasis in the contents of this level of education, its inclusion in the literature recommendations on a STSE education [1]. One of the goals of the "Millennium Development Goals" by 2015 was to halve the proportion of people without access to

safe drinking water [7]. Furthermore, the new goals and targets for sustainable development in "Agenda 2030" of the United Nations [8], beginning on 1 January 2016 and for the next fifteen years, reinforce environmental sustainability. The new global sustainable development goals are intended to stimulate action in areas of critical importance for humanity and the planet, considering the three dimensions of sustainable development: economic, social and environmental. Freshwater scarcity is mentioned as one of the most important problems to solve, in the Declaration "Our World Today" [8]: "Natural resource depletion and adverse impacts of environmental degradation, including desertification, drought, land degradation, freshwater scarcity and loss of biodiversity, add to and exacerbate the list of challenges which humanity faces". Thus, the centrality of this issue emerges also from the need of a reflection on the social, economic and environmental consequences of water scarcity.

2. Literature Review

The discussion of the implementation of laboratorial work in the teaching and learning of science continues to prove to be one of the priority areas in the didactic study of Physics and Chemistry, arousing the interest of researchers and teachers, on the use of active methodologies, particularly in projects with experimental component, which motivates students and potentiates an effective environmental education for sustainability and active citizenship.

A project can be defined as the route that takes place between the initial idea and the final result, covering the problem identification, planning of intervention, joint action, evaluation and reformulation and, if necessary, re-operation [4,9]. This is a preferred working process in

science disciplines, understanding learning as a social activity, rooted in the students' reality. The students are challenged to use their knowledge to explore, negotiate, interpret, and create products and solutions with application to emerging and real problems. This methodology emerges from the attempt to create new practices, giving students responsibility for their learning process, combining theoretical, procedural and behavioural knowledge. In addition, the project work methodology can serve as a learning process of scientific research. In the course of realization of a project, students engage in research activities, problem solving, planning, reassessment and redesign of the work that they want to develop. Individually or in group, the students can collect, analyse and interpret data, intervening in the decision-making processes [10].

The implementation of a project involves several stages, beginning at a previous time, which corresponds to the preparation of students and teachers, regarding the theme selection, the definition the methodology and institutional resources, both human and material. The next stage is the implementation phase, with defined tasks, conjoining the skills and capabilities of all participants, in common synergy. In the final stage, the preparation process of the report and the public presentation of the product and the respective report, are steps simultaneously used as evaluation and dissemination. The public presentation contains an entire work cycle and should be a time for questioning and clarification of the public's questions. The phases of a project work are inherently recursive, since they are subject to a dynamic of constant reformulation, based on continuous and formative evaluation of the journey undertaken together [4,9].

In the last decade, several authors have emphasized the importance of carrying out projects on environmental issues, based in scientific research, on real problems and laboratory activities [6,11,12]. In the curriculum proposals, for physics and Chemistry (and science in general), the role of environmental education and sustainability has been strengthened [13] involving the educational community, which interconnects the classroom to the surroundings.

Therefore, based on this brief review of the literature, the study focuses on the realization of a school project, according to a STSE environmental education.

3. Materials and Methods

The study aims to assess the effects of an intervention project in the local environment in environmental awareness and scientific literacy of high school students, in a school of northern Portugal. The project "Our Water" with a laboratorial component, coordinated by the researcher, and carried out in a STSE perspective of environmental education for sustainability had, as subjects, 86 students from 4 classes of 11th grade of Physics and Chemistry and 12th year students of Chemistry and 3 teachers.

The "Our Water" project focused on developing a set of activities involving the study of physical and chemical parameters of water.

The project had the following objectives: to promote interest in science and the development of research capacity, selection and organization of information, and

the use of diversified laboratory equipment; to determine some physicochemical parameters of water samples from wells and private mines, collected from the local environment; to raise awareness, among students and locals, that water should not be wasted or polluted, because the balance and the future of the planet depends on the conservation of water; to develop cooperative work among students in the framework of a joint laboratory project; to disseminate the results to the school and the environment.

In what, were: determination of the pH of the water; determination of the dissolved oxygen; determination of nitrate content; determination of the content of phosphates; determination of total hardness; and determination of electrical conductivity.

Being an intervention project, a research-action approach was used. Accordingly, students collected the water to be analyzed, and conducted laboratory activities necessary for the analysis of water, based on experimental protocols. At the end of the activities, they drew up reports on the scientific and laboratory research activities.

As for the evaluation, it focused on student participation in activities, on teacher's records, and on the reports written by the students at the end of the Project.

Given the complexity of the educational reality in analysis, we applied the discursive textual analysis and qualitative methodology for research, valuing the understanding of social reality as a construction and attribution of meaning. Qualitative methods face the subjectivity of the researcher and the subjects studied, focussing the interrelations, arising in the social reality, that shape and influence perceptions and behaviours [14,15].

Since it is not possible to disclose the full study, due to its length, it is only presented part of the research, conducted during two academic years, 2013/14 and 2014/15. As data collection materials were privileged students' reports in the end of the project, as well as the final report of the project coordinator. Thus, it will be made a discursive textual analysis of this report, written by the coordinator, prepared in accordance with the directions of the Pedagogical Council of the school and containing a comprehensive analysis of the project. Moreover, it will be presented a content analysis of students' reports, based on categories and subcategories defined *a priori* [16], from an evaluation grid adapted from the PARSEL project [17,18].

4. Results and Discussion

In the analysis and discussion of the results, it will be presented the analysis of the report written by the coordinator, and subsequently, of the reports made by the students.

The **Final Project Report** "Our Water" was presented to the school by the coordinator at the end of the implementation of the project in June 2015. This document summarizes the activities and the appreciation of the participants, whether they were students or teachers. Getting the report for an overview of the project locally made, with collection and analysis of wells and mine water, the coordinator notes that the objectives of it were met, in a STSE perspective. The 86 students of Chemistry,

that were participants in the project, performed in accordance with the schedule. They finished the activities planned for the collection and analysis of particular water, with determination of pH, electrical conductivity, total hardness, the phosphate content, the level of nitrate and dissolved oxygen. Having resources such as the experimental protocols and the necessary equipment, the students worked in groups, performing laboratorial activities of water analysis and drafting their individual reports.

Regarding the results obtained by the students, we concluded that all waters are acidic, which is in line with the waters of the northern area of this country. The water hardness has the characteristics of a soft type of water, which is also in agreement with the zone of the country.

As for final evaluation, in the project Evaluation Form, included in the coordinator's final report, on a scale going from "Insufficient" to "Very Good", the project was rated "Very Good" in all parameters subject to evaluation. As for teachers, their assessment of the project is positive, revealing of the connection between theory and practice, in a STSE perspective teaching of Sciences, specifically Chemistry. As regarding the students, the coordinator responsible for the project presents his opinion:

Coordinator: *"The students gave their opinion on the project at the end of the year (...) In general, the students considered that the project was very positive. The learning intentions were achieved, namely regarding the contents of the subject and the process of investigation, reflection and communication in the group."*

In order to illustrate the descriptive evaluations of students, the coordinator transcribed excerpts, included in the annexes to the Project Assessment Form. In a comment written by one of the students, we can read the positive evaluation and the respective justification:

Student 6: *"This project was really good. I struggled at first, but this work has improved my knowledge, my research capacity in the laboratory and it improved my final grade in Chemistry. I liked it, we should do more of these projects, so I evaluate the project with very good"*.

In turn, the coordinator highlights the added value of a project that could bring together efforts, under the purpose of a common action.

Coordinator: *"It is a process of scientific research and is a working path between students and the teacher, which is very important. Both the students and the teacher learn. The project work involves not only curricula of Physics and Chemistry, but also methodologies for investigation and knowing how to work together to achieve a common goal."*

Correspondingly, throughout the report, the coordinator refers repeatedly students' participation in different activities in class and outside class. Consequently, it emphasizes teaching and learning STSE, based on the commitment of young people in the environment where they live, with application of scientific knowledge and the consequent deepening of their scientific literacy and environmental awareness.

In order to highlight the importance of extra-curricular activities, the coordinator quotes the comments of two students, who mention the link between school and environment. One student describes the relevance and pleasure involved in the contact with the owners of the well, whose water his group analyzed.

Student 54: *"I also enjoyed talking to the owners, because they know the whole story of the well, the date it was built, the family who owned it before and told the whole story."*

The field trip during the sampling stage has revealed in itself to be a form of knowledge of environmental and human environment that this student was sensitive to, by emphasizing the interpersonal experience he went through.

Another student describes his participation in the project, by mentioning more environmental awareness.

Student 27: *"In this project developed in Chemistry class we used some instruments for laboratory activity. This experience worked as a starting point, helping us to understand how the process takes place and also how to become aware of what is missing, for the control of water for human consumption. Unsafe drinking water causes numerous health problems, not to mention the environmental health"*.

As discussed in the Final Report, it is visible the students' perception of the local environmental relevance of the project.

Coordinator: *"This student's written statement gives evidence of the high degree of importance given to the implementation of projects that enhance the awareness of young people to environmental issues relating to water."*

In fact, as stated repeatedly by student 27, who uses the words "understand" and "become aware", it is essential to raise awareness among young people in defence of a preserved and sustainable environment. The same applies to another student, quoted in the final report, who reaffirms the importance of water in a local and global perspective:

Student 36: *"It is important to realize that water is becoming increasingly scarce. However, in our generation, few care about this. They take it for granted and do not think about local problems and even less of the needs of a growing world population."*

Continuing his reflection, the coordinator states that the implementation of the project aimed at environmental awareness and the development of scientific literacy, promoting a procedural meaningful learning, at a high cognitive level. This learning project work, as stated in the brief theoretical framework of this article, includes several steps, recursive and collaborative, which are not an easy task for young people to carry on. The following quotation, selected by the coordinator, reveals the perceptions of a student about the complexity of the project work:

Student 61: *"It's not easy to work on a project. I find it hard, and it gets worse if the group has elements that do not like to work in groups and are always chatting. This time I was lucky with my group. We got along very well and we finished all the stages of work on time. We were the first group to finish."*

As constraints, firstly the coordinator points out that some students found it hard to structure, write and review their scientific report.

Coordinator: *"From full reports with detailed research and scientific language to weak reports, which are not according to the required levels (...). Despite the weak reports having been revised by the teacher, the desirable level has not been achieved by all students."*

Not all students are able to produce quality reports, which is worrying, given that the field of scientific language is part of the development of scientific literacy, at this level of education.

Secondly, the coordinator, while reiterating students' engagement with the project, points out the lack of timely dissemination of results, by the end of the school year 2014-15, involving the local environment, as originally planned.

Coordinator: "A weak point of the implementation of the project had to do with the poor level of disclosure of the results. As on 5th of July 2015 the teaching activities for the 11 and 12 grades ended, because of national tests, it was not possible to realize the final activity of the project, the presentation of the results in our school. That disclosure (...) is essential, given the purpose of the project to contribute to local environmental sustainability."

The dissemination of results finally happened in an open session at school, in the beginning of next school year, in October 2015, with the presence of educational and local members of the community, as recorded in the Final Report.

Regarding the analysis of individual reports of the students, a total of 86, this was made based on categories and subcategories of analysis [16] according to an evaluation grid with four levels, adapted from the PARSEL project [17,18], as mentioned before. Students' reports include laboratory work carried out under the project "Our Water". Table 1 contains the evaluation of students' reports, considering some categories and subcategories.

Table 1. Evaluation of Students' Reports

Categories	Subcategories	Oc.
1. Ideas and planning	Insufficient development of themes with little or no details	18
	Proper development of themes with some details	28
	Good development of themes with supporting details	24
	Extensive development of themes with many supporting details	16
2. General organization	Unorganized	11
	Some organization with sequence	26
	Well organized with a clear sequence	39
	Very well organized with a meaningful sequence	10
3. Data organization	Unorganized with data difficult to read	11
	Some organized data with in charts	28
	Well organized charts with some categorization	31
	Good organization and correct categorization	16
4. Data interpretation	Distortion of data and interpretation almost impossible	11
	Some distortion of data with little interpretation	27
	Data without distortion with some interpretation	43
	Good interpretation of data with reasoned interpretation	5
5. Language and vocabulary	Choice of words and simple sentences with misuse of some scientific terms	15
	Choice of words and simple sentences with correct use of some scientific terms	39
	Good choice of words and complex sentences with correct use of many scientific terms	22
	Good choice of words and complex sentences with correct use of precise scientific terms	10

Regarding the first category, "ideas and planning", the subcategory "insufficient development of themes with little or no details" features 18 occurrences; the subcategory "proper development of themes with some details" has a total of 28 occurrences; next, with 24 occurrences comes the subcategory "good development of themes with supporting details" and with 16 occurrences the category "extensive development of themes with many supporting details". It appears that there is a dominating positive assessment, although it is significant that 18 reports reveal an insufficient development of the proposed topics.

The second category, "general organization", shows that 11 students' reports were "unorganized", 26 show "some organization with sequence", 39 are "well organized with a clear sequence" and only 10 were "very well organized with a meaningful sequence".

Overall, a good organization is achieved by most students in their reports, but still many texts appear without the proper structure of a scientific report.

With respect to the third category, "data organization", the results show that, in the subcategory "unorganized with data difficult to read," there are 11 occurrences; "some organized data in charts" includes 28 occurrences; "well organized charts with some categorization" is the

subcategory that totals more occurrences, with 31, and the last subcategory, "good organization and correct categorization" comes with 16 occurrences.

Regarding the fourth category, "data interpretation", there are 11 reports in the subcategory "distortion of data and interpretation almost impossible"; with 27 occurrences, we have the subcategory "some distortion of data with little interpretation"; with the highest number of occurrences, 43, stands out the subcategory "data without distortion with some interpretation". Finally, with only 5 occurrences, comes the subcategory "good interpretation of data with reasoned interpretation." With regard to the resolution of a problem situation, the interpretation of the data implies the application of knowledge and the ability to relate *curriculum* content, calling theories, studies and authors, a high cognitive level task that few students can meet fully. Most reports of students present "data without distortion, with some interpretation" (the next lower subcategory in terms of level of achievement), but they don't reach a reasoned interpretation, essential in secondary education and further, in higher education.

As relates to the fifth category, "language and vocabulary", we have 15 occurrences in the subcategory "choice of words and simple sentences with misuse of

some scientific terms" and "choice of words and simple sentences with correct use of some scientific terms" features 39 occurrences. As for the subcategory "good choice of words and complex sentences with correct use of many scientific terms" has a total of 22 occurrences, while "good choice of words and complex sentences with correct use of precise scientific terms" includes 10 occurrences.

A significant number of reports show that many students don't have a scientific writing because they aren't able to apply properly science vocabulary and key concepts. Thus, the acquisition of a specific vocabulary is essential, through the confrontation between a language of daily life, used by students, and a scientific language, required for different types of written scientific works, such as the Chemistry report of the project "Our Water".

5. Conclusions and Recommendations

The intervention project in the local environment "Our Water" was evaluated positively by the participants. Among the positive effects, it proved the deepening of environmental awareness and scientific literacy of students. As for the advantages of carrying out the project, reference is made to the learning achieved on the water theme, a curriculum content of the discipline of physics and Chemistry, as well as the improvement of the ability to work in groups. Overall, there was a strengthening of environmental and sustainable education, as well as teaching and learning STSE, with an increasing commitment of young people in field activities. It is also important to emphasize the school interconnection to the local environment, which enabled awareness and appreciation of the environment and human sites, in what concerns environmental education. As for the constraints detected, one of which focuses on report writing, some students do not master the structure, nor the vocabulary glossary area, particularly scientific concepts. This gap is worrying, because the story of a project with experimental embodiment, using a correct and rigorous language, is one of the aspects of scientific literacy, essential to students who complete compulsory education and wish to go to the University. Another constraint is due to students' little commitment to the dissemination of the results and conclusions, which led to the postponement of the open session for the disclosure at school, although the same happened later. A final constraint has to do with the focus of the study in one school, which circumscribed the conclusions. In the future, we intend to replicate this research, with the necessary adaptations to other contexts. As a final note, the study showed the potential of STSE education and environmental education, regarding students' awareness and the implementation of sustainable practices in the local environment. This implies a greater responsibility from teachers, both in investing in their continuous training, and for creating a joint project with their students. This common pathway is essential, in order

to understand and address pressing environmental issues, as exemplified by the problem of drinking water, safeguarding the quality of life for present and future generations.

Statement of Competing Interests

The authors have not competing interests.

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