Practical Work to Promote Interdisciplinarity Between Physical and Natural Sciences: A Teaching Experiment with 7th Grade Portuguese Students

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Abstract. *The paper describes a teaching experiment carried out with thirty 7th grade students, in which practical work made possible an interdisciplinary approach between Chemistry and Natural Sciences.*

The practical work corresponded to the construction of a model of a volcano, under the topic volcanism in the discipline of Natural Sciences, and the topic chemical transformations in the discipline of Chemistry. We also present the evaluation of the teaching experiment taking into account the teachers' and students' point of views.

Keywords. Interdisciplinarity, practical work, teaching and learning of physical and natural sciences.

1. Introduction

Two main ideas are central to the Portuguese curricular reorganization of Basic Education initiated in 2001, including the subjects of Physical and Natural Sciences. The first idea concerns the attempt "to value the experimental learning in different areas and disciplines, [being] compulsory in the case of the teaching of science, to promote the integration of its practical and theoretical dimensions…" [2]. The second concerns the interdisciplinary approach to some topics and contents with the objective of "demonstrating the unifying character of possible themes, emphasizing phenomena that require scientific explanation from different areas of knowledge" [7].

2. Practical work in the teaching of science

The importance attributed to practical work in the Portuguese Science Curriculum is aligned with the main beliefs shared by experts in science education. A brief review of the literature on practical work in Science Education [11, 3, 5, 6, 10], can illustrate its importance. Practical work can motivate learning; develop scientific and analytical skills; enable an improved acquisition and comprehension of concepts; develop a solution-driven pragmatic mindset; develop discussion and critical analytical skills as well as introduce more rigor in Science Research. The issue of motivation is nowadays of particular concern [9], given that a significant portion of the students have little incentives to learn, exiting the schooling system prematurely. Therefore, the teacher should emphasize the emotional sphere and resort to experiments that go beyond simple and mechanistic implementations in order to become more fun and rewarding for the student. This value added in the emotional sphere can also represent a way to obtain better performances by the "least capable" students [9]. Reid and Hodson [9] explain that "this increasingly emotional response causes in itself a feedback movement leading to the accumulation of more cognitive abilities that can stimulate learning". The goal is to engage students in interactive teaching methods, so that science can become real and relevant in their eyes. Hence, emphasis should be placed on activities in which students have a high chance of succeeding and in which they can interact and find meaning in their experiments.

The key concept is that of "motivation", which can also take place through the curriculum itself. The latter should include three types of goals, in order of priority:

The first concerns the goals centered in the student such as overall motivation and the development of certain attitudes of self-esteem.

The second refers to the goals centered in society, enabling the framing of the contents through an interaction between science, technology and society. (stressing everyday issues, promoting an equilibrium between scientific/technological criteria as well as economic, ethical and social considerations).

The third concerns the goals that are centered in science, such as the knowledge and comprehension of scientific concepts and theories (the study and experience of phenomena); the acquisition of cognitive and psychomotor competencies (scientific practices, problem-solving); the development of a scientific attitude [9].

Together with the aforementioned potential for practical work, there are also critical perspectives with relation to how it can be conducted and consequent efficacy in teaching scientific concepts. Some authors [4, 3] consider that practical activities instead of promoting learning can sometimes promote conceptual misperceptions and thus become useless. Others [5], share the thought that in many classrooms practical training is mis-conducted, confusing and unproductive, thus contributing very little to science students' learning. Others still [6] consider that in many situations, practical work is done in an excessively hasty manner, managing the equipment in a very carelessly, so that students fail in the production of the phenomenon they were supposed to observe. Moreover, even if that is not the case, the observed aspects may seem obvious to the teachers and not to the students. Therefore, practical activities can quickly turn into a routine with no objectives for the students. Rendering practical work more efficient requires the need to think carefully about the way it is going to be used as well as the type of activities that will be adopted given the objectives and the students it is aimed at. In fact, this recommendation is explicitly reflected in the Portuguese Basic Education Curricular organization when it mentions: "the experimental activity should be planned with students, deriving from problems intended for analysis, as opposed to the blanket application of a cookie cutter approach. All cycles of schooling must privilege the formulation of hypotheses and prediction of results, as well as their observation and interpretation." [7].

3. Interdisciplinarity in science education

The definition of the role of Science in the Portuguese Basic Education Curriculum reinforces the idea that Science cannot be applied in a self-contained way, with contents that are detached from the real world. It should instead favor an integral and global perspective on Science [10]. Under this assumption, the curriculum should not be the sum of several parts but an articulated whole corresponding to an enriching dialogue between the different sources of knowledge that lie at its core. Herein rests the importance of a horizontal articulation of concepts, themes, contents and skills. In this context, the goal is for students to develop a more global understanding that goes beyond a limiting disciplinary approach. This fact requires information to migrate from other fields of knowledge, and for it to be reinterpreted in light of the problems that cannot be solved purely within the realm of classical disciplines. However, this is not to mean that as stated in the document about "curricular orientations", that disciplinary individualities will not be respected. Instead, it enables teachers to organize their classes, or at least some of the contents, collaboratively. The goal is to expose the unifying content of possible questions, stressing the phenomena that require scientific explanations originating in different areas of knowledge.

Taking these ideas into account we conducted a teaching experiment in Physical and Natural Science, which corresponded to practical work through an inter-disciplinary approach.

4. The teaching experiment

The Basic Education National Curriculum, enacted in Portugal since 2001 defines 10 areas of general competency that should be developed during Basic Education. The first consists in "mobilizing cultural, scientific and technological knowledge in order to better understand reality and to address everyday situations and problems." All competencies foresee a transversal operationalization. As far as the aforementioned competency is concerned, the curriculum suggests an emphasis on: the context and the problem so as to encourage the student's involvement and curiosity; on questioning the observed reality; on identifying and articulating knowledge and information that can enable a better understanding of the situation or the problem at hand; on the application of the necessary procedures to understand reality and solve problems; on the assessment of the adequacy of knowledge and procedures used while adjusting when necessary.

Taking these suggestions into account, we conducted an experiment in teaching on the topic of "Earth under Transformation", which is shared by Physical and Natural Sciences.

4.1. Subjects

Thirty 7th grade students, as a class, participated in this experiment.

This is the year in which students start to study the subjects of Natural Sciences as well as Physics and Chemistry, under the Natural and Physical Sciences grouping.

4.2. Description of the experiment

During the first phase, the teacher of Natural Sciences approached the students with the topic of "Volcanic Activity: risks and benefits". The study began with a discussion of news of volcanic eruptions, some referring to historical events. Then, the teacher proposed that the students build a model of a volcano as practical work to explore the issue of volcanism (Fig. 1 and 2).

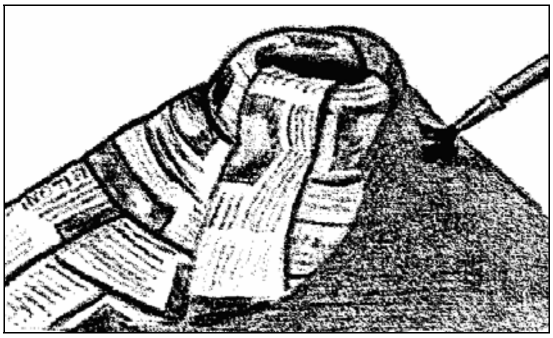

Figure 1. Model of the construction of a volcano

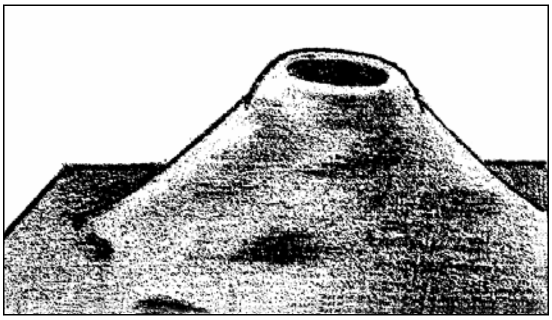

Figure 2. Final model of the volcano

Simultaneously, the teacher of Physics and Chemistry worked with students on the topic of "Chemical and Physical Transformations." In the realm of chemical transformations the question posed was: "How do some substances transform into others?". To solve this problem several day-to-day situations were analyzed and the practical work was undertaken.

During a second phase, a session of ninety minutes took place with both Natural Sciences and Physics and Chemistry teachers present. Teachers and students discussed the type of volcanic equipment as well as the type of volcanic eruptions and their main causes. They also simulated a volcanic eruption by using heated solid ammonia dichromate (Fig. 3), relating it to the study of the topic of chemical transformations and to the particular case of chemical transformations through heat.

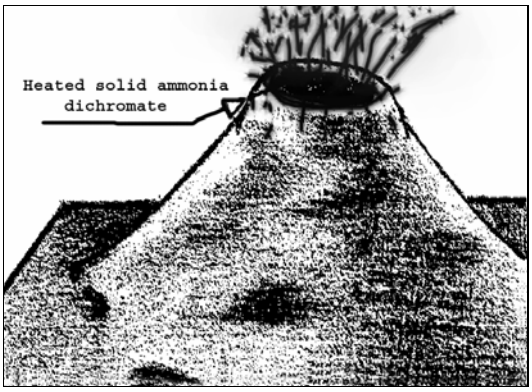

Figure 3. Simulating a volcanic eruption

In this context, both teachers and students used practical work as an opportunity to reflect upon, discuss and integrate knowledge.

5. Assessing the experiment

The techniques used to assess the teaching experiment corresponded to a direct observation of students while they worked in the classroom and responses to a questionnaire. One of the evaluations reported by a teacher, based on the perception derived from observing students, mentioned the following: “A brief and critical analysis of this experiment reveals very positive results. Firstly, not only for me but for the entire teaching body, the connection established between the programmatic contents of both disciplines was extremely important, due to a dynamic approach to both topics. As far as students were concerned, because they became active agents in the process of learning through the exploration, manipulation and observation of the phenomena, they achieved the objectives of the class and were able to adopt a critical view of the articulation of contents belonging to the different curricular areas“.

The learning experience was valued by students and expressed in some of the answers given to the questionnaire. In response to the question: “Did you enjoy this experiment?”, students stated that “ It was fun because we were able to see - through chemistry - what happens in nature, without too much effort. The entire class was interested and that is always very good”; and that “Yes because it was different and we were able to picture moreless how a volcano works while learning Chemistry.”

In response to the question – “Do you think that this strategy contributed to a better understanding of the contents of Natural Science and Chemistry?” - we obtained answers such as: “Yes, to some extent it did because it helped us learn chemical transformations much better as well as the “functioning” of volcanoes” and “Yes, because by connecting the disciplines we were able to better understand everyday situations”.

Regarding the question – “If you had to compare this strategy to another one in which teachers would teach these contents separately, which one would contribute more towards your understanding of the materials?” - the students replied that “I think the strategy of integrated teaching is better. For instance, to understand Chemistry, we need knowledge of Science and other disciplines”; and that “I think that this strategy is better because it creates incentives for us to be engaged in these activities and understand the subject matter better”.

The fourth question asked: “If you could influence your teachers regarding teaching strategies to use in the classroom, what advice would you give them given the experiment with volcanism?”. To this students answered that “These activities should be more frequent” and “I would advise them to teach more practical classes and co-teach with other teachers when the topics overlap”.

The last question, asked whether “ a strong connection between teachers and disciplines was beneficial for students’ learning”, elicited the following responses: “Yes, because we learn more about a subject if different teachers are teaching it” and “Yes, because students can learn more concepts that can be applied to other disciplines”.

All things considered, an analysis of students’ answers reveal that they have developed a very clear perception of the importance of practical work and of a global approach to phenomena. This is evident when they allude to more practical classes and the need for more cross-disciplinary knowledge.

We strongly believe that this teaching experiment is very simple without requiring sophisticated equipment. It also represents an approach that enables students to investigate real world problems, relate them to their daily lives and better understand the phenomena they are confronted with in the mass media.

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