

Experimentation in primary school: discover and understand or verify what is expected?

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Abstract. Science education in primary schools in Uruguay is still a pending task. Frequently, only biological science is taught in class. Often, activities are reduced either to look for information without experimentation, or to very guided hand-on activities with little space for actual research where results may differ from what is expected and new questions might come up. As a result, children have a partial and sometimes wrong concept of science. The idea of science as something distant from reality and ordinary life, holding absolute results and truth, is reinforced. A lot of research has been done in science didactics about the role of experimentation in order to improve scientific competences in the students. In this project we analyze the role of experimentation during the science class as well as the speech of the teacher in relation to his objectives and the planned didactic sequence. A qualitative methodology was used, through classroom observations and interviews with teachers. We chose a case study to inquire how the experiments are used in a science class and what is the role of experiments proposed by the teacher. To collect the data, recordings of classes were used and in-depth interviews were conducted with the teacher.

1. Introduction

The didactic investigation in the field of science in Uruguay still has not had an institutional framework in which to develop, consolidate and build a bank of theoretical material, and even less if it is in primary education. This is what V. Sanz Bonino [1] shows in his work for the subject Methodology of Investigation II that belongs to the Science Education degree – (*Universidad de la República*). In this work, Sanz makes a survey of the educational researches published in Uruguay in the public and private area in the period between 1997

and 2007, apart from interviews done to people who are responsible for educational management and/or for the investigation in the institutions they represent. In this period, 19% of the publications referred to topics related to didactics, but the percentage devoted specifically to Physics didactics in primary school is not established. It is very difficult to trace works of this nature, successful or innovative experiences are not always registered, that is why there is no database to which resort to.

The objective of this work is to understand the role that experimentation in a Physics class in a primary school plays. The conception that the teachers involved have about the function that is given to experimentation when teaching Physics is sought to be revealed through the triangulation of the information gathered from the analysis of the classes observed, the corresponding plans that were made and the interviews done to the teachers after class.

1.1. Teacher training in Uruguay

According to Dibarboure, M. [2] *...Es sabido que las Ciencias Naturales tienen un espacio limitado en el escenario escolar, realidad que no mejora con el tiempo. Cuando se consulta a los docentes sobre lo que ocurre con la enseñanza del área, en general argumentan que la dificultad está basada en un débil conocimiento disciplinar. La reciente propuesta curricular (2009), contribuye y refuerza esa apreciación generando mayor inseguridad...*” [“...It is known that Natural Sciences have a limited space in the school setting, reality which does not improve over time. When teachers are consulted on what happens to education in the area, in general they argue that the difficulty is based on a weak disciplinary knowledge. The recent curricular proposal (2009) contributes to and reinforces that view engendering greater insecurity...”] The primary school teachers training degree has in its curriculum a subject called Physical Chemistry, in other words, in a four-year degree there is only one annual course that talks about topics related to Chemistry and Physics. This subject is set in the first year of the degree and then, during the last year, topics that belong to these disciplines are going to be addressed again during a 30 hours workshop. It is a free-format workshop, therefore, it depends on the expectations that the group has and the professor’s in charge formation. The majority of the professors of these subjects come from the teaching degree in Chemistry as their basic training, which comes down to workshops in which many Chemistry topics are dealt with and Physics’ are weakened. If we also consider that the majority of the students of Primary School Teachers Training of the whole country have gone through a humanistic General Certificate of Secondary Education, this results in teachers who in their entire professional stage attended two Physics courses in secondary (equivalent to Key Stage 4 in the UK) and to a unique annual course (which shares topics with Chemistry) during their teaching training. This leads to understand that the low affinity that the teachers training students have to the experimental sciences has been enhanced with little training in the career. For teachers, this causes a feeling of mistrust on themselves, they do not feel prepared to work on topics related to Physics, they express insecurity before the issues to be addressed and, therefore, discontent and negative predisposition regarding these contents. A

brief diagnostic study carried out in 2007 about 675 teachers of different areas of the country revealed that 67% of respondents had had a negative story with Natural Sciences; 11% took no position for or against [3].

In the economic and productive model of Uruguay, in which basic science professionals are an important cultural capital, it is necessary to bring the scientific knowledge from a very early age and to the entire young population of the country. The so-called scientific literacy is present in various documents and public policies speeches of many countries. There is a tacit agreement about the importance of its conceptualization and scopes among a large part of the political leaders of the world. As an example, and being an important reference, in the Budapest declaration [4] that began in the World Conference about Science for the Twenty-first Century: A New Commitment and in the Santo Domingo Declaration, Science for the 21st century: a new vision and a basis for action, it is stated that science and technology education is a strategic imperative for a country that wants to cater for the fundamental needs of its population. That is why scientific education is considered an essential prerequisite for democracy and it is expected that scientific education will be education for action.

At a national level we find several attempts to support primary school teachers in science teaching, but these turn out to be isolated elements that do not always achieve the objectives of a real change of the methodologies used in the classroom. The Training Institute at Service, depending on CEIP (Primary School Board), has been coordinating for many years face-to-face workshops in all areas for those teachers at service who register.

Other recent examples in Uruguay are the materials of the repositories of *Plan Ceibal* [5]. The repositories offer finished materials but they do not always adapt to the specific characteristics of each class; although they can guide the production of their own material, they are not always applicable for each class without adjustments. The scientific clubs also represent an impetus to the scientific literacy to take into account, they have the distinctive feature of possessing influence on the entire territory of Uruguay but they cannot be considered as a “way of teaching sciences” in all classrooms. Programmes like *Prociencia* [6] had great importance but did not aim to do a scientific research on education and it is nowadays suspended. On the other hand, the book “*Física con XO*” written by Trinidad G. [7] represents an important contribution for the creation of experimental designs with the help of XO computers that the Uruguayan government distributes among students. This contribution is of great importance to teachers when it comes to creating activities regarding Physics using the XOs, but it does not provide the teacher with a theoretical framework in which to base all their strategies of Physics education and sciences in general.

1.2. International precedents

At an international level there exist various investigation groups that are dedicated to the area of Didactics of Science, specifically to Physics applied to primary education. In many cases, this investigation is done in the same centers associated to teachers’ training and, in other cases, it is done in different institutions, but all of them have a long history of investigation and systematization of experiences.

In particular, at the Faculty of Education in Sao Paulo there is an investigation group that has been working for many years in the area of education through investigation and resolution of experimental problems with very good results.

Many authors tell the importance of breaking with the distorted view of science, pointing at Science education in primary schools and scientific literacy as crucial and starting points. In this sense, making science is shown as an effective way to achieve this objective, being an effective strategy when it comes to modifying traditional teaching strategies in science. As Oliveira de Brito states “*Los resultados revelan que los alumnos, cuando invitados a hacer sus investigaciones semejantes a las hechas por la cultura científica, desarrollan contenidos conceptuales en un contexto lleno de significados. De tal manera, los alumnos se vuelven capaces de utilizar conceptos científicos como instrumentos de lectura, significación y comprensión del mundo, o sea, se alfabetizan científicamente.*” [8] [The results reveal that the students, when invited to carry out investigations similar to the ones done by the scientific culture, develop conceptual contents in a context full of meanings. This way, students become capable of using scientific concepts as instruments for reading, giving meaning and understanding the world, that is to say, they become literate in the field of science.]

2. Materials and methods

2.1. Methodology

The ethnographic, qualitative research methodology of case study was used. Although a case study accepts quantitative processes, qualitative and/or a mixture of both, in this investigation it was chosen to use qualitative processes in order to analyze in depth a comprehensive unit defined as the case to answer to the approach to the problem, test hypotheses and, eventually, develop a theory [9].

The qualitative processes were chosen since they are in line with the objectives and the types of questions raised. These questions determine using a non-experimental case design, of a unique case and of ethnographic type. The ethnographic perspective allows a complete exploration of the analyzed case and an intensive data gathering of the cultural elements present, and uses the complete range of qualitative tools to collect data. The case studies answer research questions such as how and why, and if it is taken into account that the present work pretends to investigate which role Physics plays in primary schools, choosing this experimental design can be justified.

The most appropriate tools are in-depth interviews and participant observations. According to Taylor and Bogdan [10] participant observation is understood as “*...la investigación que involucra la interacción social entre el investigador y los informantes en el milieu de los últimos, y durante la cual se recogen datos de modo sistemático y no intrusivo*”. [the investigation that involves social interaction between the researcher and the sources in the milieu where the latter are, and during which data is collected systematically and not in an intrusive way]. In this research project, the participant observation was carried out in the classroom during a normal Physics lesson. To carry out this observation, those in charge of the institution gave the corresponding permissions. Being careful when it comes to the methodology used by observers and the building of the rapport is necessary. Observers may abuse of assumptions they have already made due to their direct work in the field regarding

the way of seeing things. This risk was minimized by placing in the field three observers simultaneously and by completing a previous training, making systematic visits to earlier lessons before the main lesson. These previous visits were useful since they provided the observers with training and they helped build the rapport between the sources, in this case the teachers and the students. The day of the visit to the main lesson, it was possible to achieve that the sources did not notice the presence of the observers. This way, their behaviors did not change at all. In order to collect the data, field books, recordings and videos were used.

In order to gather data on the teachers' perception regarding the experiments in the Physics' lesson, in-depth, semi-structured interviews were carried out. Taking these type of interviews as repeated face-to-face meetings between the researcher and the sources, meetings which aim is understanding the sources' view towards their lives, experiences or situations, as Taylor and Bodgan [10] state in their own words. In this research in particular, apart from the interview, documents such as the planning of the activities used to teach Physics were analyzed as the basis for building the story of life of those lessons.

2.2. *The sample*

A primary school in Montevideo was chosen to do the work (school N°21). In order to work there, the necessary guarantees of the authorities were processed. A practice school was chosen, this meaning a school where teachers who are being trained do their practice. The reason why this was done is that these types of schools are in direct contact with academic productions regarding didactics. In this school, a third-grade group was selected (8-year-old students – equivalent to the initial part of Key Stage 2 in the UK) since it is a grade where the first learning period is finished in the public Uruguayan school.

3. **The data**

3.1. The lesson

A third-grade lesson was filmed, with a total of 20 minutes of film material. The teacher is identified as Teacher A. It is a teacher who has around 10 years of professional experience. The topic of the lesson is the classification of illuminated objects and the experiment presented to the children consisted of enlightening with a torch a piece of wood, colorless cellophane paper, another colored cellophane paper, wax paper and a bottle with water. Those objects were enlightened and, on a screen (the whiteboard was the screen), it was seen whether the light that came from the torch went through the object or not. Manipulations were done by Teacher A.

Data was collected in the moment of the experiment according to the categories of analysis established by Mortimer and Scott [11]. These authors define the *Teachers' intentions* taking into consideration the objective they have during each part of the lesson, which they call scientific history or it could also be the development or account of the lesson. These intentions fall within a social setting in which the activities are presented and, during that social involvement, learning takes place. They set six intentions which they call: 1) *creating a problem*; 2) *exploring the students' view*; 3) *introducing the development of the scientific history*; 4) *guiding students in their work with scientific ideas and supporting the*

Table 1. analysis of the episode of the lesson which includes the experiment		
Categories	Item	Details
Teacher's intentions	<i>Preserving the narrative</i>	He underpins the development of the scientific history through a demonstrative experiment, not taking into account the students' ideas at any moment.
Content	<i>Description</i>	He uses sentences which refer to an object or phenomenon.
Approach	<i>Authoritative – non-interactive</i>	He makes the whole experiment. He does not pay attention to students' concerns which arise from the observation of the experiment, like the shadows and the refraction.
Interaction patterns	<i>I-A-V</i>	He intervenes with only one question that can have only one answer and he validates that answer by saying things like “excellent” or ignoring those questions that do not fit what he has in mind.
Ways of intervention	<i>Revising the scientific history progress</i>	He synthesizes the results of an experiment in particular, summarizes what was seen on previous classes and insists on reviewing the development of the scientific history.

internalization process; 5) guiding students in the implementation of scientific ideas and in the expansion of its use, giving them, gradually, the responsibility and control of its use and, finally 6) preserving the narrative supporting the development of the scientific history. When analyzing the lesson under these categories, we find that the episode of the experiment (we call episode to those parts of the lesson that are clearly differentiated among them due to the aims and activities proposed) is neither problematized nor used to explore previous ideas that students have about this phenomenon. It is neither used as an opportunity for students to discuss the new scientific ideas presented, internalize them and be able to use them in new cases, or link them to other social and scientific fields. Nor is it presented as the availability of scientific ideas in the social sphere of the classroom, since there is no room either for debate or for argumentation among students. The experiment is rather used as a tool for teachers to make comments about the development of the scientific history such as “do you see what happens?” “Do you see that the light goes through? So if light goes through this is called a transparent object”, “do you see that in this case the light does not go through? So this is called an opaque object”. The interventions done by the teacher did not help to develop understanding of these scientific ideas with others from other fields, being this last aspect what differs from the definitions of the category proposed by Mortimer and Scott, but it was the one that best fitted of all.

Regarding *content*, Mortimer and Scott define it as the analysis of the content of the speech delivered in class and distinguish three types: *description, explanation and*

generalization. In the case of Teacher A, *description* is present since his speech involves sentences that refer to an object or a phenomenon: “this object is transparent so it lets light go through”, “this object is a translucent object since it lets light go through partially”. He uses sentences to describe the objects that are part of the materials used in the experiment. The *communicative approach* has to do with the type of interaction that the teacher sets in the classroom. For Mortimer and Scott this aspect is central in the structure of analysis of the lesson and shows how the teacher deals with the intentions and contents by pedagogical interventions that result in certain patterns of intervention.

These authors establish two dimensions for the discourse between the teacher and the students: *dialogic* or *authoritative* and *interactive* or *non-interactive* discourse. In the observed lesson, the teacher analyzed in this work showed an authoritative, non-interactive communicate approach, characterized by a discourse in which there is a specific point of view. The interaction patterns correspond to the analysis of the talking turns during the development of the lesson, noticing that they correspond to the type: teacher’s intervention – student’s answer – teacher’s validation (I – A – V). The teacher asks a question, the student answers and the teacher validates that answer with expressions such as “excellent”. Feedback patterns, where the teacher intervenes, the student answers and the teacher intervenes again in order to promote a speech reformulation by the student and give feedback, were not observed.

Finally, Mortimer and Scott regard the teacher’s interventions as the category that describes the teacher’s pedagogical interventions, providing six ways depending on the objective: 1) *shaping meanings*, 2) *selecting meanings*, 3) *pointing key meanings*, 4) *sharing meanings*, 5) *checking students’ understanding* and 6) *revising the scientific history progress*. Each type expresses itself through the teacher’s actions. Teacher A makes interventions of type 6) since he is the one who synthesizes the results of a specific experiment, summarizes what was seen on previous lessons and insists on reviewing the development of the scientific history of this lesson, since he emphasizes during each episode of the lesson the types of illuminated objects (opaque, transparent and translucent) as those that do not let light go through, those that let it through and those that do not let it go through completely.

3.2. The planning

In the planning, the experiment is presented as an activity, there are no goals of understanding for this lesson, nor any specification of the cognitive processes that are intended to be developed on the students. There are no instructions to be presented to students neither details of what are students expected to do in each part of the scientific history. It is a planning focused on content.

3.3. The interview

It was a semi-structured interview, with guiding questions with the objective of making those necessary topics for the investigation appear in the interviewee’s speech.

Hereunder, those teacher's interventions about the role of the experiment in the observed lesson are transcribed. In response to the question: *what role did the experimentation play in this lesson?* the interviewee answered:

Teacher A: "...that they can visualize it in order not to let it be just a sheet of paper or something on the board. It was a resource to prove and achieve the aim that was recognizing the different objects in relation to the passage of light."

Teacher A: "...that they can see it. We enlightened a notebook with a torch and we did not see the light on the other side, that they can see that it is an opaque object: look, the light does not go through. It is not because I say it to you, look at it with your own eyes."

When it was suggested to the teacher that he designed a new task to give to the students, supposing that they gather in 5 groups and that a kit with the same materials the teacher had in his demonstrative experiment is given to each group, the teacher designed tasks like "step-by-step recipes". After the research group encouraged the teacher to think of other different tasks, he reworded it as follows: Which of these objects are opaque objects? Which object do you think lets light go through? Or what permits light go through?

4. The analysis

The analyzed lesson corresponds to one delivered by a teacher who has around 10 years of professional experience. He showed, even from the planning, an idea of the experiment being a subsidiary activity to "fix" contents regarding science. During the lesson, the experiment that took place was a demonstrative one in which all things were done by the teacher, including observations and conclusions that were made by him as well and showed to the students. During the interview, the teacher reinforces the idea of the experiment as a "supporting" activity showing, this way, that he sees scientific concepts as given truths that have to be discovered and not as an interpretation of reality built socially. Despite the fact that it is a quite novel teacher from whom we could expect to have access to more updated academic literature, there are still positivist concepts of sciences, classifying the objects first as opaque, transparent and translucent to then check that light does not go through the first ones, totally through the second ones and partially through the last ones instead of observing first this characteristic and taking it as the criteria to classify and then categorize them. To this teacher, science is already done and it has to be discovered. There was no room for other opinions at any moment of the scientific history speech, there was no link between the content that was being taught and other fields of knowledge or aspects of the society and its current problems. Because of this, in his classroom students were not encouraged to be scientifically literate, and scientific contents were not seen as a social construction of the interpretations of the physical world. The lack of debate and the narrow shaping of the experiment could stem from the teacher's insecurity regarding technique, who does not feel comfortable when handling Physics contents efficiently. This insecurity determines the style of the lesson taught and the demonstrative experiment, with the aim of feeling in control of the lesson.

5. Conclusions

The analyzed teacher is familiar with literature about current didactics since he is novel and works in a practice school. However, that familiarization and opportunity is not showed in the lesson. He shows insecurity about his own disciplinary knowledge, portraying in this aspect some kind of loneliness that the system does not solve. In order to achieve changes in the style and conceptions of sciences education is not enough with the academic approach to new tendencies, we believe that the teaching staff needs closer support: a place where teachers can go and receive help when planning, solve doubts and be empowered to put into practice innovative ideas.

This study shows that: despite research and training, the teacher's conception of science and its teaching still remains in an old version. The teacher's ideas about how children learn and the cognitive processes that are actually encouraged by the teacher are probably similar to the ones he had experimented as student. The recommendations of the official curriculum were ignored as well as those of the research on didactics. This study shows the persistence of old ideas. Our conclusion is that it is not enough to create written documents, a closer work with the teacher is necessary to improve science teaching and update it.

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