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Secondary Students' Emotions and Inquiry Performances During their First Learning Experience in the Chemistry Laboratory

Leticia González-Rodríguez, Beatriz Crujeiras-Pérez

Universidade de Santiago de Compostela, Spain[1]

Abstract

This proposal examines secondary school students' engagement in an inquiry-based laboratory task and the emotions emerged during the learning process. The proposal is part of a larger study aimed at examining the influence of epistemic knowledge, critical thinking and emotions in students' inquiry performances and their progression. The participants were 35 secondary students' attending Physics and Chemistry lessons in a public rural high school at the northwest of Spain and working in small groups of 3-4 students.

The activity analysed required students to investigate if adding an aspirin to a vase containing a flower bouquet and water would conserve the flowers longer. To do so, students had to select a procedure and carrying it out, as well as to draw the pertinent conclusions. Moreover, students' emotions were examined before and after the investigation. For data collection, students' written reports regarding the investigation were collected, as well as the emerged emotions. The main results highlight that, in general, the small groups were able to select the best procedure for carrying out the investigation. Regarding emotions, although they showed some fear to carry out the investigation, in general they show happiness and motivation during before and after the investigation.

Keywords: *Emotions; Inquiry; Laboratory; Secondary education*

1. Introduction

The theoretical framework draws from the approach of teaching and learning science through students' engagement in the scientific practices of inquiry, modelling and argumentation, understood as the major practices that scientists employ when they investigate and build models and theories about the world [1]. The main feature of this perspective is that students should directly experience the practices for themselves in order to develop an understanding of the practices and to appreciate the nature of scientific knowledge [2]. In this paper we focus on the inquiry practice, understood as students' engagement in asking scientifically oriented questions, setting investigations, collecting and analysing data, formulating explanations based scientific evidence [3]. Within this practice, the problems that students encounter are well documented being the main constraints related to the difficulty in designing complete and well-defined procedures [4,5] and in controlling variables [6]. There is evidence that engaging students in inquiry is not enough to perform this practice adequately [7] and there is a need of addressing the epistemic aspects involved in this practice, such as the methods for obtaining data that are accepted within disciplines [8] or the criteria to which knowledge claims are held [9].

Epistemic knowledge concerns the comprehension of the role of the specific constructs involved in the production of knowledge and of the essential characteristics of the knowledge-building processes [10]. Addressing epistemic knowledge in science lessons is relevant since a higher level of epistemic knowledge allows for more productive learning about scientific practices and contents [11].

Epistemic knowledge has been examined from different perspectives within Science Education: disciplinary, personal, and social [12]. This study focuses on the disciplinary perspective, which involves aspects such as acknowledging that the outcome of a single experiment is rarely sufficient to establish a knowledge claim [13] or that it is important to conduct a clear, honest, and accurate data collection [14].

Emotions are also important in learning Science through scientific practices since they contribute to attitude formation, in this case to attitudes to science learning [15]. Emotions are formed by multi-dimensional elements that include cognitive, physiological, behavioral, and motivational factors [16]. According to Pekrun and Linnenbrink [17], emotions can be categorized under several categories according to their interaction with different educational aspects such as learning content, social interaction and others and also they can be positive or negative according to the value or the expected consequence of a specific piece of information [18]. In this paper we analysed students' emotions

before and after engaging in the inquiry task to examine the impact of the intervention in terms generating positive or negative emotions.
The research goals are:
1) To examine students' epistemic performances related to the inquiry practice.
2) To analyse the emotions emerged during the intervention and their evolution.

2. Methodology

This study is framed in a qualitative approach, and it draws from qualitative content analysis [19]. The participants were two classrooms of secondary students attending Physics and Chemistry lessons (N=35) in a public rural high school at the northwest of Spain and working in small groups of 3-4 students.
The activity analysed in this proposal is set in an authentic context that required students to investigate if adding an aspirin to a vase containing a flower bouquet and water would conserve the flowers longer. To do so, students were required to select the best procedure from 3 options, justify their choices and carrying it out, as well as to draw the pertinent conclusions. Moreover, they were required to select the emotions they felt from a set of positive and negative ones before and after the inquiry task. It needs to be noted that the students were not familiar with the inquiry practice as well as with laboratory experiences and, by the time of the intervention, they were learning about scientific methodology.
For data collection, students' written reports regarding the investigation were collected, as well as the emerged emotions. For the analysis different rubrics regarding the inquiry operations and the emotions were developed in interaction between literature and data.

3. Results

3.1 Students' epistemic performances in inquiry

In this section we focus on two inquiry operations, planning the investigation and drawing conclusions. In relation to the planning most groups (8 out of 9) selected de adequate procedure. The analysis of their justifications in terms of frequency is reproduced in table 1.

Table 1. Students' justifications to the selection of the best procedure for conducting the investigation.

Category	**F**
a. Justification based on epistemic knowledge	1
b. Justification based on scientific methodology	3
c. Justification based on their predictions	1
d. Justification by a process of elimination	1
e. Not justified	1

According to table 1, only one group provides a justification of their selection based on epistemic knowledge related to inquiry, proposing the following: " *It's procedure C because it contains a more specific and concrete steps, therefore the results will be more reliable*". In this example students are considering the need of obtaining reliable results in an investigation, which is an epistemic aspect of inquiry, although they forget other aspects such as accuracy or replicability. The other justifications are related to the steps of scientific methodology or based on their predictions.
Regarding the conclusions drawn by students after conducting the investigation, all groups proposed a conclusion responding to the research question, however there are different levels of performance, as summarised in table 2.

Table 2. Analysis of students' conclusions

Category	**F**
a. Conclusion backed on empirical evidence	3
b. Conclusion backed on non-adequate evidence	3
c. Conclusion backed on evidence that do not reflect the expected results	1
d. Conclusion not backed on evidence	2

Three of the 9 groups draw a conclusion based on the empirical evidence collected during the experiment, being one example the following: *"The experiment went well. The best way to preserve flowers is in water, as they are still preserved today. However, the flower with water and aspirin broke*

after four days and after six days it started to wilt. In conclusion, if you want to preserve a flower, just put it in water".

3.2. Students' emotions related to the inquiry practice

In relation to students' emotions, the positive ones prevail over the negatives both before and after the inquiry. There are three positive emotions that are more frequent than the others: confidence and motivation selected by 19 out of the 35 students, and fun selected by 17 students. Regarding the negative emotions, the most common ones were nervousness proposed by 11 students and tension and boring selected by 10 students.

In terms of evolution, it needs to be highlighted that although the number of positive emotions remains almost the same at the beginning than at the end of the inquiry, the negative emotions decrease considerably from 68 to 42 and there is only one that appears frequently, concern, selected by 9 students.

4. Conclusions

The findings highlight a positive impact of the inquiry intervention in students' inquiry performances and also in their emotions, however epistemic knowledge is little identified in students' performances.

Epistemic knowledge is crucial for an adequate engagement in the practice of inquiry, students' need to be aware of why it is important to plan an accurate and well-defined procedure as well as the need of replicating an experiment or the need of drawing evidence-based conclusions. Therefore, this type of knowledge needs to be explicitly addressed in lessons so that students can mobilize it in their performances.

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