Use of narratives on scientific experiments in the teaching of redox reactions in secondary education

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Abstract. This study presents the implementation of narratives in a school chemistry laboratory; the narratives were directed to improving the learning about oxidation-reduction reactions among secondary students. The aims of the study are to characterize students' written narratives based on their lab-work and to categorize different 'types' of narratives related to how they approach scientific knowledge. We identify the application of 'cognitive-linguistic skills'. Students conducted a series of school science experiments (on oxidation-reduction) following a set protocol provided by the teacher. Once the lab activity was completed, they were asked to write a text ('experimental narrative') on it; the narrative became part of their laboratory report. Analysis of the narratives shows that a high percentage of students approach the written reconstruction of the experiment in a descriptive way. According to the categories applied in this study, the use of experimental narratives favors 'reflective' scientific learning.

Keywords: Secondary school chemistry, Redox, Lab work, Experimental narratives.

1 Introduction

In the process of teaching chemistry, it is essential for teachers to obtain information on what students learn and on the ways in which they can communicate what they are learning. An important means to get this information is via school scientific experiments: teachers encourage students to question phenomena of the natural world through experimentation. Experimentation in the school laboratory contributes to the understanding of scientific concepts and procedures, to the use of key scientific notions and skills in order to develop new understandings, and to the discussion of ideas on the nature of science [1].

We believe that it is of the utmost importance to develop and implement activities that allow students to rebuild their knowledge; such 'rebuilding' can be fostered and at the same time demonstrated by engaging in the production of written texts. The activity of reconstructing school scientific experiments through writing involves what can be called 'cognitive-linguistic skills' [2]: procedures based on complex cognitive abilities and conveyed through oral, written or multi-semiotic texts, which foster the development of competences of scientific thought. The whole process provides a way of incorporating the normative knowledge of chemistry and of using it to interpret the chemical world.

Scientific conceptualization of natural reality is based on a set of shared representations of the objects under study. Although reality exists beyond its representations, theories that explain it are built on the basis of language(s). Therefore, reality is to a certain extent 'constructed' through very elaborate talking and writing on phenomena. Theoretical models are the intellectual tools that help us understand phenomena, intervene on them, and construct text-based explanations [3].

Many studies have been conducted in didactics of science regarding the nature of students' understanding of natural phenomena. These have shown that, before formal learning, students hold their own viewpoints and have their own explanations on phenomena, using everyday language that differs –in terms and syntax– from that of scientists. Thus, in what has become a classic text, Roger Osborne and Beverly Bell [4] distinguish between what they call 'students' science' and 'scientists' science': the former comprises perspectives on the world and meanings of terms that students have constructed before receiving science instruction, while the latter refers to the views widely accepted in the scientific community.

Science learning is a continuous and autonomous process of knowledge-building by each individual, though not in an isolated manner, but rather through extensive interaction with other people and objects (teachers, peers, teaching materials). In science classes, teachers ask students to read, write and talk; in the lab, students make observations and interventions and communicate their results. This variety of activities constitutes a conglomerate of processes under on-going communication and evaluation; this is precisely what enables the construction of scientific knowledge among students. Different authors [5] [6] state that learning science is done through the progressive appropriation of scientific language, in association with the incorporation of new ways to see, think, talk and act on facts; such ways differ from every day, common-sense ways of seeing, thinking, talking and acting. Thus, through scientific language students can get access to a different culture, the scientific culture.

2 Theoretical Framework

2.1 Scientific narratives

From a theoretical perspective, a narrative serves to frame and ground any substantive linguistic exchange: “We can conceive narrative discourse more minimally and more generally as verbal acts consisting of someone telling someone else what happened” [2]. This ‘minimal’ definition makes reference to a narrator (someone saying), a recipient (someone who receives the narrative, which in this case will be called the ‘reader’), events (something that happened), and a timeframe [7]. Linguists also identify other characteristics of any well-constructed narrative: e.g., structure (i.e., correct concatenation of elements), agency (actors performing actions to advance the storyline), and purpose (the aims towards which the agency is directed).

The implementation of our didactical strategy involving narratives in the science laboratory aims to help moving language and thought from the everyday to the scientific. Therefore, the incorporation of narratives into chemistry teaching is valuable to students’ learning insofar as it encourages the development of the communication skills of explaining and arguing, while it also stimulates deeper reflection regarding particular scientific notions [8]. According to Sanmartí and Jorba [9], narrative is the most common structure of the texts that we usually use in everyday life. Narrative as a category often includes all others, as a narrative text can contain dialogues, descriptions, explanations, etc. To be considered a narrative, the text as a whole need to have additional traits: cohesion, subjectivity (i.e., a viewpoint), and chronological ordering of events.

2.2 Characteristics of the narrative structure

Following [9], it can be said that the structure of a narrative always contains: 1. three distinct phases: introduction of the situation, development, and outcome; and 2. linguistic elements that relate the events with time, i.e., temporal connectors and adverbs (Table 1).

Table 1. Elements in a narrative structure.

Types of text	Morphology and syntax	Textual and other aspects
Written or oral texts: -Stories, reports, narration of events, etc. -Biographies.	Perfective verbs: distant past or recent past. Elements that provide structural relations to verb tenses:	-Chronological order of events and ‘narrative order’ (alterations of the chronology for rhetorical purposes). -Parts of the

- Fictions, tales, news, historiography, etc.	- Time adverbs. - Temporal connectors, conjunctions and locutions, etc.	narrative: introduction, development/climax, outcome (‘dénouement’). -Narrative viewpoints: characters’ perspectives, external narrator, etc.

Scientific narratives in the form of scientific reports are a discursive genre that can be used by science students to express their ideas on the scope and validity of a certain scientific position. In a study on the rhetoric of the experiment [10], Azuela states that scientific narratives in general and experiment reports in particular are pieces of rhetoric (in a conventional definition of the term), as their objective is to persuade or influence. Scientific discourse is a discourse of power, in which rhetoric should be understood as the use of language with the aim of being effective in communication, and this includes convincing through discourse.

In our study, we conceptualize a scientific narrative as “the discursive sequence that includes the ideas the author wishes to transmit and the facts that justify those ideas in reference to the author’s models regarding science and its development” [11].

In the context of school science, scientific language is learned by talking, reading and writing, and by thinking about these processes, but too much emphasis is given to the writing and evaluation of very stereotyped texts, such as lab reports [12]. Therefore, the use of scientific narratives can be a distinct contribution, since it implies understanding scientific language as literary language [13], as a tool for creating and comprehending the world. In the narration of their own scientific ideas, students need to understand a set of key concepts in order to reasonably describe how they are conceiving phenomena and explaining them to themselves and others. In the process of textualizing the ideas in an elaborate format, those ideas, and the words students use to shape them, become more coherent with the theoretical models they hold [8].

Narratives on experiments are an instrument that can have advantages for reporting on laboratory practice [7]. An experimental narrative is a way to reconstruct first-hand experience with the phenomenon in order to give meaning to that experience through language. Such reconstruction can be understood as the production of an elaborate ‘factuality’ combining ‘real’ facts accessible to experience and very stylized transformations of those facts through linguistic resources [8].

Our decision to use experimental narratives is based on recognizing that it has been shown that they represent a means of facilitating modeling processes. They are also a strategy for improving memory and increasing interest in learning and comprehension of what has been learned. In addition, they can be used to reflect the fundamental structure of students’ conceptualizations: making public students’ private thought [14]. Narratives facilitate the appropriation of diverse cultural knowledge, providing a framework for dialogue between emotions, reason and experience [15]. They can be used as a tool to ‘play’ with experiences in two ways: making the incomprehensible comprehensible and making the comprehensible incomprehensible, as both actions contribute to our knowledge of the world and how we interact with it [13].

2.3 Students' difficulties in learning redox reactions

The literature has classified the recurrent difficulties faced by students when thinking about oxidation and reduction into two types: conceptual and procedural [16]. Conceptual difficulties include the following:

- The notion that oxidation and reduction reactions can occur independently.
- The explanation of electron transfer.
- The meaning and designation of states of oxidation. Procedural difficulties include the following:
- Identification of reagents as oxidizing or reducing.
- Imprecise terminology and linguistic complexity hindering the identification of the involved substances and their roles.
- Solving equations that are difficult to understand, giving excessive emphasis to the importance of following established procedures (e.g., ion-electron method).

Another difficulty frequently seen is the definition of redox related to 'oxygen transfer': this idea is very attractive to students, as they can argue the participation of oxygen instead of electron transfer. A study [17] shows that when students are asked why a metal changes appearance, most explain it from a macroscopic viewpoint, arguing that this change is caused by the exposure of the metal to conditions such as moisture, sun, water, etc. Few students refer to the redox process, though they understand that electrons are involved in a reaction. The same study also shows that there is a conception that oxygen always participates in a redox reaction. When the students give explanations of these phenomena, they generally have problems with the microscopic explanation and the abstraction of the behavior of atoms and the interaction of particles. They thus illustrate phenomena through facts, such as the coloring of the solution, which help identifying the experimental behavior of the system, but do not account for what has occurred.

3 Methods

The objective of our study is to identify and characterize narrative styles among secondary school students when they explain oxidation-reduction reactions. Our study is based on students' original productions. We categorize and describe 'types' of 'school scientific narratives' using two indicators: how they approach scientific knowledge, and how they use cognitive-linguistic skills.

This study analyses the narratives constructed on an experimental activity performed by students who use a protocol they are given. Once the activity was completed, the students were asked to write a text ('experimental narrative') about the subject in question (oxidation-reduction). The narratives formed part of the students' laboratory reports and data was collected from them for this investigation. The corpus of data is constituted by the narratives written by a class of 30 high-school students (aged 17) who participated in the lab activity.

The suggested task was the following: "After completing the lab activity, we would like you to write down your experience. Please write a minimum of one page on the full laboratory experiment you have just done; do not leave out any details, describe what you did, what you saw, what you analyzed, how you felt and what you learned. Also try to relate the things you studied in the laboratory with processes that occur in everyday life".

Considering that data for our research is under the form of written texts, our data analysis, in accordance with Bardin [18], is based on text segmentation into units of analysis, thus allowing identification of different meaning units that make up the narrative text. This requires assigning codes in order to be able to classify the units of register in the document, and classifying the written material for subsequent description and interpretation. This so-called 'open coding' aims to express the data in the form of concepts, corresponding to a first-order analysis. The texts were coded in order to:

- Establish regularities to identify different structural dimensions in the narratives: a) introduction, b) development, and c) conclusion.
- Establish regularities to recognize different cognitive-linguistic skills in the narratives: a) description, b) explanation, c) justification, and d) argumentation.
- These four categories are understood as follows:
- Description involves producing statements that present the qualities, properties, characteristics, etc., of an object, organism or phenomenon.
- Explanation entails producing reasons or arguments in an orderly manner following cause-effect relationships.
- Justification needs providing reasons or arguments in relation to a corpus of knowledge or theory.
- Argumentation is also producing reasons or arguments, but with the main aim of convincing.

4 Results and Discussion

For the purpose of categorizing the 30 narratives that we collected, two analyses were performed: one on the structural elements, and one the cognitive-linguistic skills that are used.

4.1 Analysis of structural elements of the narratives

Forms of introducing: connection to knowledge. The first structural element is the introduction. It allows identification of different starting points and the ways in which students deal with their own knowledge. While some students only describe the instructions received, others begin by proposing ideas on the phenomenon and use their past experience as an element to frame and give meaning to what they have done.

Forms of developing: connection with phenomenon. Development is the longest part of the text and mainly includes descriptions of the procedure, ways to approach the phenomenon and decision-making in the execution of the lab. Students establish a dialogue with the activity, they describe the steps taken for each redox reaction, the reflections, the physical changes observed, the successes and failures, and they even include some anecdotes.

Forms of concluding: reflections on the activity. In the conclusions of the texts, we identified more reflections from the students on the implications of the experiment, the expectations they had, their difficulties, and the expected learning.

4.2 Analysis of the cognitive-linguistic skills present in the narratives

All 30 narratives were again considered in this second analysis. They were coded according to the four main cognitive-linguistic skills that we had selected: describing, explaining, justifying, and arguing. The coding corresponds to the presence of fragments in which one of those skills can be identified.

Our analysis led to coding 138 text paragraphs, classified under the three skills that could be found.

In general, description is the skill most commonly identified in the narratives of the experiment, with a frequency of 87%. This may be showing that students favor visualization of the phenomenon in terms of observation. Argumentation is not seen in any of the texts, showing the difficulty faced by most students when they intend to elaborate a strongly organized set of ideas in a written format that requires precision, coherence and the use of warrants or backings. This finding may also be related to the traditional way in which science classes are conducted, beginning by presenting the 'sheer' concepts without any associated phenomena to be modeled. Such classes are neither aligned with current proposals on chemistry teaching based on a constructivist approach, nor consistent with what the philosophy of science tells us on the ways in which scientific knowledge is generated. This could explain the lack of higher-order abilities, such as explanation and justification, in students' narratives.

5 Conclusions

In the light of our preliminary results, which we have presented here, the inclusion of experimental narratives in chemical education is only the first step towards the development of higher-order scientific skills, such as explaining, establishing a theoretical basis, providing evidence, justifying, and finally arguing. Considering that a high proportion of the students are only descriptive in their retelling of the scientific experiment, it is necessary to generate scenarios in which they can be helped to make concrete advancements in the development of more robust texts that include more elaborate skills.

According to the categories employed in this study, experimental narratives favor a space of reflective 'textualization' of the scientific experiences. The narratives created by students show that for them this genre is a useful means to summarize the activity; narrative writing constitutes a task where students can think back on the experiment and express their impressions, and even emotions, regarding it.

The multiple values of this task that we proposed lead us to conclude that it has a positive influence in students' learning, beyond what is usually achieved in this kind of activities when the traditional experiments are performed, but no written reconstruction is demanded. Specifically, regarding the acquisition or consolidation of theoretical concepts, though many of the 'descriptive narratives' use more colloquial than scientific language, it can be seen that some incorporate more critical and reflective elements to account for the results of the experiments.

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