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DEVELOPMENT OF A RESOURCE FOR THE TEACHING OF CHEMICAL FORMULAS AND ITS APPROPRIATION BY TEACHERS

Abstract: Teaching the symbolic language, the concepts of submicroscopic and macroscopic models, of the empirical register should be done in a dialectical way to encourage the students to make links between the different registers and levels. The symbolic language acts as a bridge between macroscopic and submicroscopic levels. Relying on the history of chemistry makes it possible to highlight the reasons that have led to current chemical formulas. Therefore, we designed a resource based on the controversies in the history of chemistry. We followed a method close to that of the Model of Educational Reconstruction to develop a resource on the introduction of chemical formulas for grade 8 students in France. The resource was proposed to four teachers and implemented by two of them. The principal steps and results of the process are presented.

Keywords: chemistry, symbolic language, teaching material development

INTRODUCTION

The symbolic language of chemistry may seem apparently simple and natural (Bensaude-Vincent & Stengers, 1993). A student may become competent enough to manipulate a chemical equation without really understanding the underlying concepts and associated models (Talanquer, 2011). The symbolic language enables both to represent the model register and the reality-as-idealised (Gilbert, Pietrocola, Zylbersztajn, & Franco, 2000; Kermen & Méheut, 2011) and to act as a bridge between the macroscopic and submicroscopic levels (Taber, 2013). It is considered as a meta level of knowledge (Canac et Kermen, 2016). A research conducted with French students showed the difficulties in learning chemical formulas (Canac et Kermen, 2016), confirming many studies already conducted on this topic (Taskin & Bernholt, 2014). We assume that teaching the symbolic language, the concepts of submicroscopic and macroscopic models, of the empirical register in a dialectical way could encourage the students to make links between the different registers and levels. We designed a resource to put this hypothesis to the test.

To develop the resource, we followed a method close to that of the Model of Educational Reconstruction (Duit, 2007): clarification of the content, elicitation of the students' difficulties, determination of the teachers' needs, building of a pilot resource, appropriation and use of this resource by volunteer teachers, analysis of the implementation in the classroom, modification of the pilot resource.

PURPOSE OF THE STUDY

The history of chemistry shows that the symbolic language, empirical knowledge and models have developed jointly. Relying on the history of science makes it possible to highlight the construction of knowledge and the disagreements that may have arisen, and finally the reasons that have led to current scientific knowledge. Taking this into account would help the students to give meaning to concepts.

Drawing on the controversies identified in the history of science, we worked out a pilot resource on the introduction of chemical formulas for grade 8 students in France. The pilot resource contains a selection of historical texts and a two-part scenario. In the first part the students are introduced to the different systems of

representation developed by 19th century chemists. In the second part, the students are expected to look for the reasons (Orange, 2005) that enabled chemists to develop chemical formulas jointly with the fundamental concepts: chemical species, atom, molecule, chemical change. We seek to determine whether this resource is accepted by the teachers, how they implement it and what effects it produces on the students.

METHOD

The pilot resource was presented to two teachers, M and X, then modified after analysis of this first implementation, and proposed again to two teachers, A and Y. All of them were filmed, interviewed pre and post session and M and A had previously been filmed during an equivalent session. Some students' notebooks and a written assessment made by A were collected. We examined how the teachers took the resource into account and the changes M and A made compared to their previous session. Following the double didactic and ergonomic approach (Vandebrouck, 2013), we explored the cognitive and the mediative components of their practices. Therefore, in each session we noted the chemical contents taught, the work organisation (who does what? When? How?). Then we analysed their discourses regarding the registers of chemistry, the macroscopic and submicroscopic levels and examined whether the level of the symbolic language they used was specified. Post-session interviews provided some reasons for the teachers' choices. We also examined how the students understood the material provided with the resource.

RESULTS

The pilot resource

In the first part, the students are told to choose between different symbols proposed by chemists (Hassenfratz and Adet, Dalton, Berzelius) to realise that the language of chemistry is a human construction subject to evolution (Matthews, s. d.). In a second stage, some Dalton's and Gaudin's texts are presented to the students to elaborate the reasons (Orange, 2005) that enabled chemists to construct the formulas of water, oxygen and hydrogen.

Analysis of the implementation of the pilot resource

The resource was submitted to two teachers M and X who both rejected the second part considered too complicated. Moreover, they did not understand the reasons given by chemists. We studied the implementation of the first part by one of them, M, who had been observed the previous year in an ordinary teaching session. We noted that his class management was unchanged, the terms used regarding the macroscopic empirical level and the submicroscopic model were still imprecise, the tasks had more varied goals, the students proposed a wider range of writing chemical formulas (e.g. OCO, COO, OOC) which were accepted by him although he did not think of them the year before. Such activities may favour the students to consider that, for instance, H₂O and HOH represent the same thing, which most French students do not think (Canac & Kermen, 2016).

The modified resource

After this first implementation, the second part of the resource was totally modified. We decided to focus on the opposition between Dalton's ideas and those of atomist-organic chemists on chemical formulas. To make this controversy more accessible, we designed dialogs between three interlocutors based on Galileo's dialogs as de Hosson did (de Hosson, (2011). These dialogs feature Simplicio who uses Dalton's simplicity criterion and Salviati who relies on atomicity introduced by atomist organic chemists (e.g. Kekule). Sagredo is the mediator.

Analysis of the implementation of the modified resource

Two teachers A and Y implemented the modified second part of the resource. Both teachers asked some students to read the dialogs and the rest of the students listened carefully. Y modified the scenario proposed in the resource. During the interview we understood that he did not grasp the chemical phenomena at stake in the resource. We previously filmed a session where A did not use the resource, the results regarding this second session are contrasted. A used the resource without modification probably because we met her to explain the purpose of the resource. The students seemed to enjoy reading the dialogs and according to the teacher they performed better in the exercises which involved the chemical reaction. Indeed, A did not address the concepts successively as she did before but together which enables the students to make links. Nevertheless, she still did not realise that the dialectic between submicroscopic and macroscopic levels is necessary because it is fundamental in chemistry teaching (Barlet, 1999).

CONCLUSION

The analysis of the implementation of the pilot resource led us to modify the second part to take the teachers' epistemological difficulties into account. The analysis of the unfolding teaching session shows that the implementation of the resource does not change the mediative component of their practices. The results obtained with the students are promising but addressing the networked concepts needs to be pursued. The next step of this work is the dissemination of the resource which needs to train the teachers and offer them to develop their didactical and epistemological knowledge.

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