MULTIPLE REPRESENTATIONS IN DEVELOPMENT OF STUDENTS' COGNITIVE STRUCTURES ABOUT THE SAPONIFICATION REACTION

Mónica Baptista, Iva Martins, Teresa Conceição
University of Lisbon, Portugal
E-mail: mbaptista@ie.ulisboa.pt, mariaconceicao@campus.ul.pt

Abstract

The purpose of this research was to know what the effect of the use of multiple representations (MR) was in the development of the students' cognitive structures. This research was conducted in three Grade 12 classes, in a total of 68 students. A Word Association Test (WAT) was used as data collection instrument. The results from WAT show that students' cognitive structures progressed from pre-test to pos-test, with an increase in the number of response words and connections between words.
Keywords: *multiple representations, cognitive structures, word association test, saponification reaction.*

Introduction

Conceptual understanding in Chemistry requires observing phenomena at three levels: macroscopic (e.g., seeing and manipulating objects, experimenting with and describing the properties of materials); submicroscopic (e.g., understanding and explaining observations in terms of non-visible and abstract objects such as atoms, ions and molecules); and symbolic (e.g., translating the understanding of observations through chemical equations, analogies and model kits) (Johnstone, 1982). Studies have emphasized that combining these three levels is essential for effectively learn Chemistry (e.g., Talanquer, 2011). However, students have difficulties in moving from the macroscopic level to the symbolic and submicroscopic levels (Prain, Tytler, & Peterson, 2009). This movement implies that students must develop their logical and abstract thinking skills, as well as their cognitive structures, that involve connections between terms, concepts and process (Derman & Eilks, 2016).

In this sense, considering the importance of students being fluent in all three levels of Chemistry (macroscopic, submicroscopic, and symbolic), it is essential to use various learning resources that help them move between these representational levels. The use of representations has been pointed out by several researchers as one of the facilitators for explaining phenomena in Chemistry, enhancing students' conceptual comprehension (e.g., Ainsworth, 1999; Gilbert, 2008). The use of two or more representations, when studying a concept is considered as learning with multiple representations (MR) (Tsai & Treagust, 2013). MR have a fundamental role in understanding concepts and the relationships between them (Gilbert & Treagust, 2009; Tsai & Treagust, 2013), which implies the development of students' cognitive structures, and as a field of research in education that has been gaining relevancy. Although most research indicate that the use of MR favors students' conceptual learning in Chemistry, there still aren't many studies concerning how MR influence the development of students' cognitive structures. This research intended to contribute to the increase of knowledge in this area. The following research questions guided this research: what is the effect of the use of MR in the development of students' cognitive structures about saponification reaction?

Research Methodology

This research followed a pre-experimental one group pre-test-post-test design, providing an intervention during the experiment (Creswell, 2002). This design facilitates the comparison of students' cognitive structures change, before (moment 1) and after (moment 2) a sequence of lessons on saponification reaction, using MR. This research was conducted in three Grade 12 classes, including a total of 68 students (36 = 57% female and 32 = 43% male; age range 17-19) who attended a school in the Lisbon metropolitan area in Portugal. Students belonged to the upper-middle class. In the 12th grade Chemistry curriculum, one of the topics is again Organic Chemistry, in which students encounter concepts such as acyclic and cyclic aliphatic hydrocarbons, aromatic hydrocarbons, functional groups and chemical reactions between organic compounds, among others. This research was focused on a chemical reaction, the saponification reaction. The three classes on the saponification reaction (total duration 360 minutes) were taught by three Chemistry teachers. Each teacher conducted the lessons in their class using MR, such as video, laboratory material, models kits and chemical equations. In this research a Word Association Test (WAT) was used as data collection instrument. The Word Association Tests (WAT) was developed by Johnson (1967, 1969). In WAT implementation, the researcher or educator selects relevant concepts (stimulus word) and asks students to write words associated with these concepts (response words) in a certain period of time (Nakiboglu, 2008). According to Bahar, Johnston and Sutcliffe (1999), WAT are considered as a "snapshot" of the students, since they do not have the time to prepare themselves and thus what is visible is the "raw state" of their cognitive structure. Through the quantity and quality of the associated words, the understanding of the concept can then be evaluated. The WAT was applied in two moments of the research - moment 1/pre-test (M1): three weeks before lesson 1; moment 2/post-test (M2): three weeks after lesson 3. To stimulate the association of words, four words were given to the students, each on a separate blank sheet: ester, alcohol, soap and basic solution. The WAT data analysis was performed based on the response frequencies map method (Nakigoblu, 2008). It began by analyzing the terms associated with the stimulus words. Words that were "meaningful", i.e., the response words of the students related to the saponification reaction were counted and validated as response words. The frequency table was constructed by placing the stimulus words in the first row, in the second row the pre-test (M1) and post-test (M2) moments, and the response words were placed in the first column. In addition to the frequency table, we constructed a table illustrating the number of different responses to a given stimulus word at the two moments (Derman & Eilks, 2016). The number of different responses to a word is a direct indication of the "meaningfulness of the key concept" and a word without associations has no meaning (Bahar et al, 1999).

Taking in account the data presented in the frequencies tables, the students' cognitive structures maps were constructed at moments M1 and M2. In order to distinguish the nature of the connections that students establish between words, a qualitative analysis of the sentences written by the students was performed, allowing us to include examples of answers for each of the frequency intervals.

Research Results

In order to examine the effect of a sequence of lessons on saponification reaction using MR in the development of students' cognitive structures, a table of frequencies (Table 1) was built, which indicated the number of response words per stimulus word at two different moments: M1 (pre-test) and M2 (pos-test). The data presented in Table 1 were used to construct the maps of the students' cognitive structures for each moment: M1 (Figure 1) and M2 (Figure 2).

Table 1. WAT frequencies table at pre-test (M1) and post-test (M2).

	Stimulus words							
	Ester		**Alcohol**		**Soap**		**Basic solution**	
Response words	M1	M2	M1	M2	M1	M2	M1	M2
Ester				28	3	66		34
Alcohol		32			1	33		16
Soap	2	67		43				65
Basic solution		42		26	26	62		
Polar					51	56		
Non-polar					52	54		
Solute							61	63
Solvent			57	33			62	65
Micelle					16	37		
Fat		43		8	65	67		9
Carbon chain	32	24	36	22		26		
Hydroxyl group		12	51	52	17	45	47	52
Carboxylic acid	24	32						
Glycerol		17		38		18		12
Hydrolysis		3				21		17
Chemical transformation		14			5	8		14
Bond break		6				9		
Saponification		4				13		
Nucleophile								5

In Figure 1, at the strongest association level of students' cognitive structures, between 61≤f≤70 frequency range (Level 4), only two stimulus words- "soap" and "basic solution"- appeared. "Soap" was associated to only one response word, "fat", and "basic solution" was associated to two response words: "solute" and "solvent". Some excerpts of the students' phrases for this frequency range revealed the nature of the connections: "soap is used to remove fat"; "in a basic solution, the solvent is water and the solute can be sodium hydroxide". These examples showed that, at M1, students related soap to fat removal and that only two of the students identified fat as reactant in soap production. At level 3 (51≤f≤60), the word "soap" was also associated to two new response words: "polar" and "non-polar". Also, at this level occured the stimulus word "alcohol", to which students coupled two response words: "hydroxyl group" and "solvent". The stimulus words "alcohol" and "basic solution" were connected to each other via the response word "solvent". Some of the sentences written by the students were: "the soap has a polar end and a non-polar end"; "the functional group of alcohols is the hydroxyl group"; "alcohol is the solvent in an alcoholic solution". From these examples, it can be inferred that most students associated alcohol to the solvent in an alcoholic solution, but not as a product of the saponification reaction. At level 2 (41≤f≤50), a new association appeared between the stimulus word "basic solution" and the response word "hydroxyl group", which was represented by the thinner arrow in this cell. At the frequency range 31≤f≤40 (Level 1) the stimulus word "ester" appeared for the first time and it was connected to the word "carbon chain", which, in turn was also linked to the stimulus word "alcohol". The cognitive structure of students at the post-test (M2) is presented in Figure 2 and it is clear that, when compared to the one at the pre-test (Figure 1), it has more stimulus words per frequency level and that all the stimulus words are connected. Accordingly, at level 2 (61≤f≤70), which was the strongest level association of students' cognitive structure, three of the four stimulus words appeared interconnected, forming a network with the stimulus words "ester" and "soap", strongly associated. The association between "soap" and "basic solution" was not so strong. Another strong association, which was also present at M1, was among the stimulus word "soap" and the response word "fat". Finally, it was observed the association between "basic solution" and the response words "solute" and "solvent" that was also present at M1. Furthermore, a qualitative analysis of the students' phrases showed that the nature of the connections at M2 was related to the saponification reaction. For instance, it was stated that "in order to obtain soap we have to break a fat (olive oil), which is an ester, and add a basic solution (NaOH)"; "soap is formed from an ester (a fat), with a basic solution, in which the solvent is water and the solute is sodium hydroxide". The other level, level 1 (51≤f≤60), was characterized by the presence of all stimulus words whereas at M1, this only happened at the frequency range between 31≤f≤40.

Conclusions

Effective student understanding of the saponification reaction entails their ability to explain it, by making use of multiple knowledge representations at the three levels: macroscopic, symbolic and submicroscopic. However, to enable students to move across these three levels, it is crucial that the teaching strategies used facilitate the development of their cognitive structures. In the present study, the strategies applied during the teaching using MR (video, laboratory materials, photographs, kit models and chemical equations) assisted that development. In fact, data from WAT shows that students' cognitive structures progressed from M1 to M2, with an increase in the number of response words and connections between words, and with a change in the nature of these connections.

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