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Stoichiometry Teaching: Highlighting Methods of Reasoning to In-Service Teachers Training

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Abstract

Considering the current scientific and technological development of society, the imposition of new needs on Science Teaching is increasingly evident, which impacts on teachers improvement courses to be offered. The aim of this work was to structure a teaching-learning sequence (TLS) provided as in-service course, held in twelve 3-hour meetings in the first half of 2017, with Chemistry teachers of Itumbiara city in the state of Goiás, Brazil. We started applying a inquiry form to teachers of the public schools, in order to carry out a survey about their formation, about difficulties encountered in the accomplishment of daily work. Also, their view on the reality of the Chemistry teaching in High School Brazilian public schools in general and in the specific case of the schools in which they work and, their conceptions about continuing education were requested. After this first analysis, a semi-structured interview was implemented with some randomly selected teachers to identify their training needs. The stoichiometry theme emerged from these findings. Taking into account the universe of knowledge improving of the participants, the psycho-cognitive and didactic principles agreed for the TLS design were supported by Gérard Vergnaud's Conceptual Field Theory. This model redirects the Piagetian focus of the epistemic subject to the subject-in and tries to answer the central question of how people learn in a situation. The sociocultural principle of design aimed at valuing teacher knowledge and experience, and providing, through a shared study, other forms of appropriation of knowledge. The authors acknowledge FAPEMIG by financial support.

Keywords: *Chemistry Teaching; Stoichiometry; In-service Teachers Training*

1. Introduction

In service teachers training is an organized effort to improve the performance of personnel already holding assigned positions in a school setting or to implement a innovation, especially in Science Education. Since 1990 active learning approaches put the students as the protagonist in teaching learning process, aiming to develop competences and knowledge within a specific culture.

Teachers must be mediators, as practitioners, trying to understand how their students are building their own knowledge, and then providing opportunities to develop and modify understandings, stablish connections and negotiate with others, mediating subject-object interactions and. They also help the student to develop confidence, adaptability and responsibility, as well as realizing that there are alternative ways of seeing reality and solving problems.

Pre-service teachers training represents only first step of learn to teach, teachers need formation throughout life and career, pre-service undergraduate could just only prepare to start teaching. In service teachers training is a demand of collective work and the aim of this work was identify training needs, promoting reflections about the practice and autonomy. We implemented a Teaching Learning Sequence devised with Chemical teachers of Itumbiara city, Brazil. Our foundations were History of Science and Vergnaud's Conceptual Fields Theory.

Thus, initially, we interviewed teachers, using semi-structured questions about their academic background, their beliefs about continuing education; which should, in their opinion, be included in the program of a short course that meets their training needs at that moment. At the same time, both the teachers and the students of the High School were investigated, which contents considered by them as more complex for teaching and learning the ones traditionally addressed in the discipline of Chemistry, which allowed to select the topic of Stoichiometry, listed as the most difficult to understand. It was also decided to contemplate some concepts related to Thermal chemistry and Electrochemistry, to meet other diagnosed needs and their relations with the content of Stoichiometric Calculations.

2. Theoretical Considerations

Some researchers (SCHMIDT 1990, 1994, 1997; PRESCOTT; BEALL, 1994; GORIN, 1994; BOUJAOUDE E BARAK, 2003; VEROVEZ; RECENA, 2007; TRISTÃO; DEFREITAS-SILVA; JUSTI,

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2008; TÓTH E SEBESTYEN, 2009; GULACAR et al, 2013; COSTA; SOUZA, 2013) point to stoichiometry as one of the most difficult topics to be understood by students, at the same time of paramount importance, since it interferes directly in the understanding of many concepts of chemistry, in the productive and industrial processes, and has application to various everyday situations. Stoichiometry is essential for solving problems and for understanding the ways Chemistry has developed as Science. Cotes e Cotuá (2014) [6] emphasize that students are, for the most part, able to solve problems with stoichiometric calculations, but lack a qualitative understanding of the concepts involved in their resolution.

However, understanding and elaborating representations are complex tasks, and can be better explained through a theory of conceptual learning that fits into cognitivist theories, where such representations play an explanatory role in these processes and allow the generation of more efficient instructional methods. In this sense, Vergnaud's Theory presupposes that knowledge is organized in conceptual fields, acquired by the subject over time, through experience, maturity and learning. Such conceptual fields constitute cutbacks of the physical world associated with cultural components and can be defined as "an informal and heterogeneous set of problems, situations, concepts, relations, structures, contents and operations of thought, connected to one another and probably intertwined during the acquisition process".

According to Vergnaud, conceptualization is the central problem of the process of knowledge acquisition. The author believes that the essential factor of students' difficulty in solving problems is not related to the separation between procedural knowledge and declarative knowledge, but closely linked to "operations of thought" [7]. Thus, the domain of a conceptual field does not occur quickly but progressively, from different situations and the formation of schemes to overcome the conceptual difficulties faced by students.

Vergnaud designated schema as the invariant organization of behavior or modus operandi for a given class of situations and considers them to consist of four elements: schema goal, rules of action and control, operation invariants and possibilities of inference. Of these, only operative invariants are essential in the articulation between a situation faced by the subject and the scheme used by the subject to solve it [9].

Since the conceptualization is content specific and not logical or purely linguistic operations, or social reproduction or the way of processing information, when studying this process, care must be taken to ensure that student's thinking capacity is not reduced. This makes the theory of conceptual fields complex, it requires the development of the concepts and theorems of progressive and premeditated situations to be solved depending on the subject's cognitive level [7]. Vergnaud seeks to show is that a concept is not formed in just one type of situation, and a situation cannot be explained from a single concept, it takes a long process of construction and appropriation of concepts and situations for that there is learning.

3. Methods

After an initial analysis of the questionnaires results, adopted as our starting point, a semi-structured interview with some randomly selected teachers was carried out to complement the data, as well as to identify theacher's training needs and define the content of the course. After, it was implement the bibliographic research for an in-depth study on continuing education, use of the History of Science for teacher training, stoichiometric calculations and Conceptual Field Theory as keywords. In the sequence, a course was prepared for teachers of High School Chemistry and others of Natural Sciences and Mathematics Areas, as a way to support the teacher in his practice, valuing his knowledge and experience and providing, through a shared study, other ways of appropriating knowledge. The course was offered through an action of the Federal University of Uberlândia, with a total of 12 meetings lasting 3 hours each. The meetings took place on Saturdays, between April and July 2017. The activities that were part of the course were organized as shown in Table 1.

Table 1. Teaching Learning Sequences Details

Activity	Situations	Schema
How many grains are in the pot of beans? What is the mass of a sheet of A4 paper?	Pupils should be presented with a glass jar full of beans and a few sheets of A4 paper. They should predict the amount of beans in the pot and the	Empty the pot and weigh it, put the beans to know its total mass and then weigh 1 grain to know its mass. Divide the total mass by 1 grain mass to estimate the amount of grain present in the pot. Use the same reasoning for the sheet of paper. Weigh a certain amount of

	mass of 1 sheet of paper using a weighing-machine.	sheets together folded, counting the amount. Then divide the mass of the leaves by the amount to discover the mass of a unit.
Directed study of Chapter 9 of the book "Elementary Treated Chemistry" by Lavoisier.	Directed study of Chapter 9 of the book "Elementary Treated Chemistry" by Lavoisier. Comparative analysis of units and physical quantities.	Represent each reactions described by an equation, and describe the quantities of reagents and products in a standard unit of International System.
Determination of purity degree of commercial caustic soda by titration and normality calculation.	Experimental procedure.	Calculate the molar concentrations of HCl and NaOH. Follow the procedures outlined in the procedure guide. Obtain the normality, using the equation N1. V1 = N2.V2. Calculate the corresponding mass of NaOH from the titrated caustic solution using the normality formula, and then convert it into percentage. Calculate the purity content of NaOH, by means of the obtained mass and the molar mass. Answer the other questions through the interpretation of the experiment.
Prepare the sandwiches.	Each group of students should receive 8 slices of bread, 8 slices of cheese, and 9 slices of ham; with these ingredients prepare sandwiches and then represent the result as a generic equation.	Each group needed to pay attention to reasoning proportional. Rules of action: the equation must faithfully represents the concrete result.
Activities about chemical transformations and forms of representation.	1: The students will receive a card with adapted activities on the chemical transformations, starting with a discussion about the circular representations created by Dalton in comparison to the Lavoisier's one and to the present one. 2: Dalton's ideas on the composition of matter. 3: Forms of representation of substances and rearrangement of atoms	1: Students need to understand the discussion of models of atoms differentiating the concept of chemical elements proposed by Lavoisier and Dalton, in order to understand the present representation. They would realize that forms of representation are complementary and change over time. 2: To establish relations between the constitution of matter and the characteristics of the physical states in which it presents itself. 3: Explanatory scope of the model. Mobilization of information as mass, to elaborate the model that leads to the number of particles.
Directed study of the translation of chapter 4 (sections 1, 2 and 3) of the Book of John Dalton	Directed study of the translation of chapter 4 (sections 1, 2 and 3) of the Book of John Dalton "New System of Chemical Philosophy", Comparative analysis of units and physical quantities.	Represent each reactions described by an equation and describe the quantities of reagents and products in a unit of measurement customary today.

Analysis of the Chemistry textbooks about the content of Stoichiometry.	Analysis of the specific chapter inside Chemistry textbooks, evaluated by Brasilian Didactical Book Program about the presentation and content of Stoichiometry.	Criteria: (1) type of images present in the textbook and their connections with the text; (2) language and scientific rigor; (3) proposed experimental activities; (4) historical evolution of content; (5) content contextualization; (6) methodological approach to content; (7) relationship of content with technological development; (8) aspects inherent to the exercises and problems that are made available.
Proust Law.	Proportional ratio between reagents and products masses in a chemical transformation.	Action rules: mass comparation. Ordenation
Mass, mater quantity and number of particles.	Avogadro's sinthesis – the mol definition (mol).	Realization of calculations and reinterpretation of previous situations with the new quantity.
Experiment "The electrical conductivity in different materials".	1: conductor or insulation rating. 2: Faraday's contributions and imagination about microscopic world; fundamental concepts in Electrochemistry	1: Verify, through an apparatus with incandescent lamp, the electrical conductivity of several materials in different conditions and represent the experiment result in a table. 2: Establish relations between the composition of the materials and the electrical conductivity, and the movement of the microscopic particles in the different physical states of matter.
Reaction Yield	Weight ratios between reagents and products: predictions and yield of chemical processes.	Calculate quantities.
Experiment "Heat released in reaction".	Stoichiometric relations between reagents and products masses and the amount of heat released or absorbed in the chemical transformations.	1: Reproduce the observations made during the experiment in a descriptive table. 2: Perform calculations to verify the relations between mass and energy in a reaction.

4. Concluding remarks

The course made possible the selection and organization of the materials, which will be restructured in the form of a guide for teachers of High School Chemistry and will also be made available in a blog along with other didactic resources. It should be noted that these activities and the exchange of experience during face-to-face meetings and also through interaction through social networks are very important for teachers, since they learn a great deal by sharing the problems found in their profession and it is in activities related to the exercise of their work that he acquires continuous training. For, in this way, theoretical learning is positively complemented by activities aimed at the professional reality and complementary courses enrich the teacher training. In this sense, it is possible to affirm that Conceptual Field Theory can provide an understanding of the relationships involved in a given concept and, consequently, to signal changes in teacher practice, more conceptual security and possibly better teaching practices.

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