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THE STUDY OF CHEMICAL TRANSFORMATIONS: AN ANALYSIS OF CONCEPTUAL CHANGE AT THE BEGINNING OF HIGH SCHOOL

O estudo das transformações químicas: uma análise da mudança conceitual no início do ensino médio

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Abstract

To understand the phenomenon of chemical transformations in high school, students need to comprehend the idea of conservation of matter and of non-conservation of substances during the process. By considering the hypothesis of hierarchical integration, this article aims at showing the conceptual changes produced by junior high school students through the use of a Teaching and Learning Proposal (TLP). Due to the learning difficulties presented by the students, the TLP was structured around three assumptions which are considered basic for the studying of chemical transformations: concepts (conceptual cores); approach models (macroscopic, symbolic, submicroscopic); and strategies (problem solving and counter suggestion). Qualitative research, characterized as a case study, presents the comparison between pre and posttests, in addition to the microgenetic analysis of learning, which evaluates in detail how these changes occur in a given period of time. The research was carried out with four volunteer students in four individual meetings (sessions) organized in three stages: pre-test, development of the TLP and posttest. Content analysis was the methodology employed to analyze the outcomes. Results show that both the individual theories explained by each student and their constructions involve a process that encompasses the elaboration of models with different levels of complexity, which coexist and are mobilized according to the problems proposed, being structured by a mixture of ideas constituted by implicit theories and scientific theories, that is, in the process of conceptual change, the students built new conceptual structures (each in their own time), without abandoning those that already existed, so that, they gradually differentiated and redesigned their interpretations aiming to the understanding and use of theories organized around scientifically accepted models.

Keywords: Teaching; learning; chemical transformations; concept change.

Resumo

Para entender as transformações químicas no início do ensino médio, os estudantes precisam compreender a conservação da matéria e a não conservação da substância durante o processo. Considerando a hipótese da integração hierárquica, este artigo tem por objetivo mostrar as mudanças conceituais realizadas por estudantes ingressantes do ensino médio por meio da utilização de uma Proposta de Ensino e Aprendizagem (PEA). Com base nas dificuldades apresentadas pelos estudantes, a PEA foi estruturada por três pressupostos considerados basilares para o estudo das transformações químicas: conceitos (núcleos conceituais); formas de abordagem (macroscópico, simbólico e submicroscópico); e estratégias (resolução de problemas e contra sugestão). A investigação qualitativa, caracterizada como um estudo de caso, com a análise microgenética da aprendizagem, contou com a participação de quatro estudantes voluntários em encontros individuais organizados em três etapas: pré-teste, desenvolvimento da PEA e pós-teste. A metodologia utilizada para análise dos resultados obtidos foi a análise de conteúdo. Os resultados mostram que tanto as teorias individuais explicitadas por cada estudante quanto às construções por eles realizadas, envolvem um processo que perpassa a elaboração de modelos com distintos níveis de complexidade, que coexistem e são mobilizados de acordo com as problematizações propostas, estruturando-se por uma mescla de ideias constituídas por teorias implícitas e teorias científicas, ou seja, no processo de mudança conceitual, os estudantes construíram novas estruturas conceituais (cada um no seu tempo), sem abandonar as que já existiam, de modo que, gradativamente, foram diferenciando-as e redescrevendo suas interpretações, objetivando a compreensão e utilização de teorias organizadas a partir de modelos cientificamente aceitos.

Palavras-chave: Ensino; aprendizagem; transformações químicas, mudança conceitual.

INTRODUCTION

The process of core notions learning implied in the understanding of concepts in Chemistry throughout high school is marked by difficulties on the part of the students; such hindrances have been analyzed in many research projects (Andersson, 1986, 1990; Barker, 2000; Boz, 2006; Driver, 1992; Herron, 1975; Justi, 1998; Liang, Chou, & Chiu, 2011, Lopes, 1995, Mortimer & Miranda, 1995; Nakhleh & Samarapungavan, 1999; Nakhleh, Samarapungavan, & Sağlam, 2005; Pozo & Gómez Crespo, 2009; Rosa & Schnetzler, 1995; Treagust et al., 2013). Much of these difficulties are related to the conceptual changes that need to be made by students to understand and use of the concepts of science and chemistry (Adadan, Trundle & Irving, 2010, Benlloch, 1997; Cooper, Corley & Underwood, 2013; Eymur & Geban, 2017; Gómez Crespo, 2008; Karatas, Ünal, Durland & Bodner, 2013; Liu & Lesniak, 2006; Pozo, 1999, 2008; Pozo & Gómez Crespo, 2009; Tao & Gunstone, 1999). It is considered that in this process of conceptual change students need to be aware of their implicit theories and, most importantly, they should perceive that their theories are different from the ones they studied at school in chemistry classes.

Among the distinct models that attempt to explain conceptual change, implicit theories are built by individuals throughout their lives, based on regularities they observe in the behavior of objects and people, providing certain theories of implicit nature about how the world is organized and what we can expect from it. In other words, students' explanations to the phenomena under study, which are grounded on principles other than the ones that structure scientific knowledge, are a result of how they understand these phenomena, based on their personal experience (Pozo, 2008).

Studies such as the ones performed by Pozo (1999, 2008), Pozo and Gómez Crespo (2009), indicate the differences between students' implicit theories and scientific theories. According to this author, students' notions rely on assumptions with epistemological, ontological and conceptual principles that are radically different from those underlying scientific theories. So, should educational institutions make students abandon their implicit theories and adopt the scientific ones provided by teachers? The process is not so simple; the teaching of content does not guarantee students' understanding of the concepts and, most of the time, students end up memorizing scientific theories for school evaluations but keep on resorting to their implicit theories to account for day-to-day needs.

By characterizing the classroom as a place for students to dialogue, reflect and ask questions, then comparing implicit theories to scientifically accepted theories is a way to build new knowledge. This construction of new knowledge does not involve the replacement or disposal of students' individual theories; rather, it implies raising awareness of the characteristics that distinguish their ideas from the theories proposed. As indicated previously, students' views are not accidental, but the result of a cognitive system that tries to make sense of a world defined not only by the relationship between physical objects present in the world, but also by the social relations and cultural factors that are established around these objects. "*It is not surprising, therefore, that it is so difficult for teachers to get rid of them, for they constitute much of our common sense and of our cultural tradition*" (Pozo & Gómez Crespo, 2009, p.95).

Given that these implicit theories have a character that is distinct from explicit theories of scientific knowledge, it is necessary that teachers know their students' explanations for the facts to be able to organize the teaching and learning proposals in a way that high school chemistry classes are places for the teacher to create necessary conditions for students to replace their implicit theories (Pozo, 2008). In this work, it is understood that replacing implicit theories means promoting conceptual change according to the hypothesis of hierarchical integration (Pozo, 2002, 2008; Pozo & Gómez Crespo, 2009), that is, students need to build new conceptual frameworks so that they can describe their interpretations within more complex structures. There are different understandings of the process called "conceptual change" (Vosniadou, 2008). It should be noted, however, that this paper will address the conceptual change, considering it as a process in which there is not necessarily the abandonment of the student's implicit theories, they are equally effective in every day contexts and social interaction, but this work use hierarchical integration in the new explicitly elaborated theory. To the Pozo (2008, p. 484) "*to know more is to make better use of the knowledge available according to the goals and the conditions of the task*".

According to Pozo (2008), misinterpretations are examples of the constraints the lower levels of the learning hierarchy impose on the structures of knowledge, which can only be avoided by clearly explaining the differences between both forms of knowledge, thus learning is not only about acquiring new representations, but also being able to activate the ones that are most suitable to the context or the demand of the presented task. To the Pozo and Gómez Crespo (2009), the student passes for three processes of theoretical restructuring: a change of conceptual structures, in different degrees of reorganization, progressive explicitness which is a process of scientific knowledge construction in which the student gradually becomes aware of his implicit theories in order to re-describe knowledge in terms of more potent conceptual systems, and the hierarchical integration of various forms of knowledge that enable the student to differentiate and integrate them in a coherent way. In addition to the methodological issues, it is also important students be aware of the existence of different forms of representation for the phenomena studied by chemistry. It became evident in studies carried out previously (Silva & Del Pino, 2009, 2014) that the explanations provided by students in problem-solving tasks contemplated different levels indiscriminately, failing to understand that they are used as representation models. It seems it was not clear to students that a model is not a copy of the reality, much less the truth itself, but a way to represent it that originates from personal interpretations (Ferreira & Justi, 2008).

Johnstone (2000) presents a model in which there are three closely related forms of representation of chemical knowledge that can be represented by the corners of a triangle. None of them is superior to the other; in fact, they are complimentary. These forms of knowledge are: (a) the macro or tangible: that can be seen, touched or smelled; (b) the submicroscopic: atoms, molecules, ions and structures and (c) the representational or symbolic: symbols, formulas, equations, molarity, mathematical manipulation and graphs.

At the macro level, chemical knowledge would be what is done in the laboratory or in the kitchen, that is, an experimental situation we are used to. However, in order to better understand chemistry, it is necessary to analyze submicroscopic situations, in which the behavior of substances is interpreted in invisible and molecular terms and recorded in a representational language. This is the backbone of knowledge as an intellectual pursuit, and also its main weakness in teaching situations, or more importantly, when students try to learn. This is at once the strength of our subject as an intellectual pursuit, and the weakness of our subject when we try to teach it, or more importantly, when beginners (students) try to learn it.

Students' implicit theories are usually situated in the macroscopic level, given that chemistry deals with codes and languages in the other two levels, thus forcing students to re-describe their sensory experiences of the macroscopic world in the symbolic and in the submicroscopic level. To Johnstone (2000), the simultaneous introduction of the three forms is a recipe that will surely lead to an overload of information which students will have difficulty to deal with. Therefore, one must begin where students are: some information, processing a certain point of view, things they perceive as interesting or familiar and then, according to the objectives of the study, organize information related to representational and submicroscopic levels.

Hence, the study presented in this article aims to show the conceptual changes produced, considering the hypothesis of hierarchical integration, by the use of a Teaching and Learning Proposal (TLP) at the beginning of High School, as well as to analyze in detail how changes take place during the development of the proposal. The study of chemical transformations, focusing on core concepts for the understanding of the conservation of matter and non-conservation of substances, was the subject chosen to be addressed in the proposal.

This paper is organized in order to present a theoretical justification involving the assumptions that led to the model used in the construction of the TLP, followed by the methodology used and the analysis of the results obtained.

Teaching and Learning Proposal (TLP) – Theoretical Assumptions

Many difficulties for the understanding of chemistry are related to teaching strategies. In order to change this, students should be less passive and become more active during the learning process must stop being passive receivers (of concepts). If students participate more, develop ideas and think about them, they will be aware of their own implicit theories and build new knowledge that will be useful in the following school years, as well as help them understand problems experienced in everyday life. Therefore, teachers should elaborate activities that enable students to differentiate the levels of representation within a context of analysis, and use them consciously and consistently with the objectives of the situations under study. This means mediating processes of comparison and differentiation of the distinct levels of representation, which, according to Johnstone (1982, 2000), is supposed to occur in a gradual and organized fashion so as to facilitate rather than hinder learning, In addition, it is understood that many difficulties related to the learning of content in chemistry classes are related to the lack of understanding of core notions of chemistry that imply understanding models in the symbolic and submicro levels.

Investigations carried out by Gómez Crespo (1996), Gómez Crespo, Pozo, Sanz and Limón (1992), Gómez Crespo, Pozo and Guitérrez Julián (2004), Pozo and Gómez Crespo (2009), present three core concepts that would be directly linked with most of the difficulties and 'concept errors' that appear in the study of chemistry, respectively related to the understanding of matter as something discontinuous, the conservation of unobservable properties and quantifying these relationships. These authors claim that the study of the difficulties of learning chemistry may be simpler if one takes into consideration that, far from being isolated, most of these difficulties are closely related. Therefore, most contents of basic chemistry may be organized around these three core concepts.

To Gómez Crespo et al. (1992), understanding the conservation of certain properties of matter is necessary to explain all processes in which it undergoes transformations, either physical or chemical. The concept of conservation is directly related to the notion of discontinuity of matter, in such a way that the assimilation of this notion could be considered a necessary, but not sufficient, condition to understand the conservation of matter in the various transformations it can suffer. What lies behind a chemical transformation belongs to the unobservable world, and refers to, once again, these tiny particles that constitute the hidden structure of matter. Thus, this is one of the most difficult problems to overcome in the understanding of chemistry, which hinders the understanding of the concept of chemical change and, ultimately, the chemical structure.

It is noteworthy that, according to Gómez Crespo et al. (1992), the core concepts are hierarchically related, so that each one influences the assimilation of the others, that is, understanding the discontinuous model of the matter is necessary, but not sufficient, to understand conservation in the transformations of matter.

Thus, considering the aspects presented on teaching strategies for conceptual change in chemistry, the different representational levels and the core notions for the understanding of chemistry, the TLP was organized not as a recipe to be reproduced by other teachers, but as a possibility, through the interaction between the knowledge produced by research in education and the school practice, to create opportunities for students to build new knowledge. According to Johnstone (2000, p. 10), "the research literature has been dominated by works on misconceptions, but there are still few studies on how to reverse or prevent this."

The present study highlights that problem solving and counter suggestion are significant teaching strategies for conceptual change in chemistry**,** because these are, according to our previous studies (Silva, 2008, 2011), activities in which students' reflection and action play a fundamental part. They can be employed together, separately or along with other strategies such as exercises, simple research or practical experiments, among others.

The problem-solving strategy is a situation in which students should not follow automatic procedures to solve problems in a faster way; it requires, to a certain extent, a process of reflection or making a decision about the sequence of steps to be followed (Pozo & Pérez Echeverría, 1998). When drafting a problem-solving task, the teacher must be sure about the objectives of the activity to be developed to be able to monitor and evaluate the constructions carried out by the students during the search for solutions. The purpose of problem-solving activities is not simply to activate students' implicit theories, but mainly to make them become explicit, encouraging students to reflect on them when they need to communicate them to others and to themselves Pozo & Pérez Echeverría, 1998).

Additionally, through the use of counter suggestion, the subjects are presented with an explanation that is different or contrary to their own in order to see if they stick to their initial ideas, which could reveal that their convictions are firm and not the product of any suggestion given by the interviewer (Delval, 2002). For this author, it is advisable to tell them that the explanation provided was given by a boy of their age and not by an adult, so that they do not tend to accept this answer for reasons of authority. This strategy allows the analysis of acceptance or rejection of what was suggested by the students. If they accept it and restate what they had said before, the interviewer should go on. If they reject the suggestion and, above all, give arguments for doing that, it can be understood that their views are well established. For this reason, it is interesting to consider the counter suggestion strategy a helpful tool when it is not possible to be sure about the subject's ideas, or even when the interviewer does not know if his opinions influenced the explanations given by the students.

According Chalon-Blanc (1997), counter suggestion is one of the strategies used by Jean Piaget in the interviews of the Clinical Method; it is particularly useful in situations in which the subject is silent when questioned, and may encourage him to resort to more flexible arguments. The present research did not employ Piaget's clinical method, but adapted it to give students the chance to compare their ideas to the ones allegedly presented by other students, allowing them to analyze other points of view and think about their own explanations.

The concepts discussed in the TLP are considered fundamental for the understanding of most of the contents studied in chemistry during basic training, and therefore must be learned and acquired early in high school. Thus, the use of the TLP proposes:

- Create conditions for students to present their ideas (implicit theories) about the phenomena under study, i.e., give them opportunities to formulate explanations and evaluate the distinct possibilities presented, without punitive assessments, so as to foster raising awareness and facilitate the demonstration of theories;

- Consider the implicit theories diagnosed during the process to, by challenging them, enable students to differentiate the characteristics of everyday theories and scientific theories, aiming at the restructuring of knowledge;

- Create opportunities for different forms of representation used in chemistry to interpret the facts under study as a means to overcome interpretations only in the macroscopic level, that is, mediate the construction of more complex and efficient models to understand the properties and transformations of matter;

-Foster the use of scientific theories studied in different contexts, by gradually introducing problems that require new levels of interpretation.

The assumptions considered fundamental for the organization of the TLP in this study are summarized in Figure 1.

Objectives

The study was organized according to objectives underlying the following questions:

1) What are the students' implicit theories at the beginning of high school?

2) Which conceptual changes occur as a result of their participation in the TLP?

3) How do conceptual changes occur during each student's learning process?

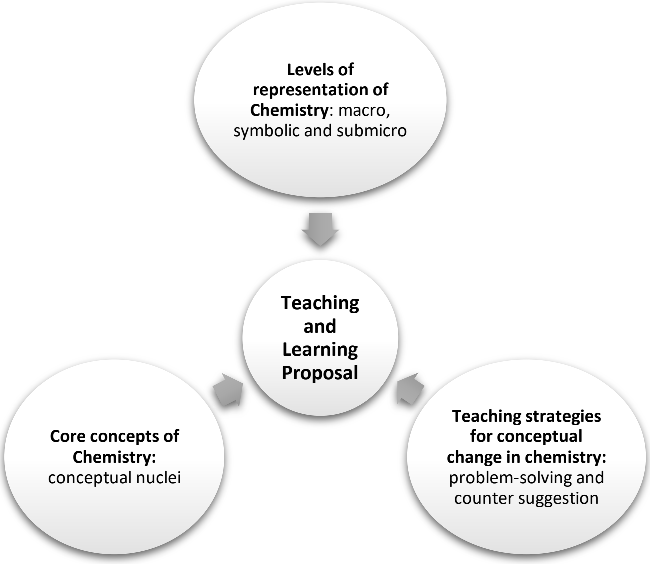


Figure 1 - Basic assumptions of the TLP

The Teaching and Learning Proposal was organized to be conducted in four meetings with different activities described below.

METHOD

Participants

The present work constitutes qualitative research, characterized as a case study (Leon & Montero, 2003; Lüdke & Andre, 2017). It consists of individual meetings with four first-year high school[1] students (identified by pseudonyms to protect their identities) from a state school in Porto Alegre - RS – Brazil. The volunteers, aged 14 -16, formally agreed to participate in the survey and presented a consent form signed by the participants' parents. The tasks carried out in the individual meetings of TLP, which lasted forty to sixty minutes, were audio recorded and later transcribed. The volunteer students produced written material that was also considered object for data analysis.

The participants were appointed by their teachers for being hardworking and showing good academic performance in chemistry. This criterion is based on Herron (1975), who claims that, contrary to what most teachers tend to believe, incorrect scientific explanations are not held only by students who are not committed to learning. Good students, who consciously make an effort to be successful, do not seem to be able to understand abstract ideas, given that they fail to progress in their intellectual development to the level of formal operations. There are dedicated students who strive to succeed in their studies, however they cannot comprehend abstract concepts because they have not yet built the structures necessary to assimilate such knowledge.

Procedure

The whole process involved three phases:

I. Initially, each student answered a questionnaire (pretest), aiming to know how they make sense of situations that would be studied during the TLP.

II. Second, students participated individually in the four meetings (study steps proposed by the TLP). These meetings were recorded and later a transcription was made. Students' written production was also taken as data to be analyzed. At this stage, it was applied methodology for studying knowledge in transition:

1 In Brazil the first year of High School corresponds to the tenth year of studies of a regular student.

Microgenetic Learning Analysis (Parnafes & diSessa, 2013) that aim at improving the learning theories, considering the processes, mechanisms and categories of scientific knowledge, concerning a moment-by-moment explanatory account of learning in a particular context, and then, opening consideration of relevant aspects of data.

III. Finally, another questionnaire (posttest) was answered by each student. The posttest questions had the same objectives of the pretest. The idea is to ask different questions, but with the same goal!

Both pretest and posttest consisted of multiple choice quizzes developed by Pozo e Gómez Crespo (2009) and Gómez Crespo (2008) in their investigations, as well as questions drawn from information obtained in previous research studies (Silva, Ritter, Piacheski & Del Pino, 2012; Silva, Piacheski & Del Pino, 2013; Silva e Del Pino, 2014). The questionnaires consisted of eleven questions regarding situations based on the two core concepts (Pozo & Gómez Crespo, 2009) that were the object of study throughout the development of the Proposal of Teaching and Learning. The alternatives of answers, both in the pretest and in the posttest, correspond to different possibilities of representation, as shown below:

Table 1-Questions of both pretest and posttest and alternatives of answers

Questions	Representations present in the answers
Questions 1, 2 and 3 about discontinuity and emptiness	Nothing. Continuity of matter
	Notion of emptiness
	There is more of the same substance
	Air in between particles
	Another substance in between particles
Questions 4, 5 and 6 about intrinsic motion	Rest. Static particles.
	Action of external agent that causes particles to move
	Intrinsic motion of particles
	Action of internal agent that causes particles to move
Questions 7, 8 and 9 about transformations of matter	Transmutation of matter
	Macroscopic properties for the particles
	Action of an external agent that causes the release of particles
	Change interpreted according to kinetic model
Question 10 about conservation of mass in a mixture	Nonconservation (disregards mass of solute)
	Nonconservation (attributes an intermediate mass value)
	Conservation of mass
	Nonconservation (attributes a higher mass value)
Question 11 about conservation of mass in a chemical reaction	Conservation of mass
	Nonconservation of mass (attributes a lower mass value)
	Nonconservation of mass (attributes a higher mass value)

Bellow, it will be presented some examples of questions applied to the pretest and posttest:

About discontinuity and emptiness:

We have a full glass of water resting on a table. What do you believe there is between water particles?

a. Nothing, there is no space between the particles. They are very close together.
b. A free space between particles in which there is nothing.
c. More water.
d. Air that fills the free space between the particles.
e. Another different substance.

About intrinsic motion

On a plate we have a piece of butter that we just cut with a knife. In your opinion, how are the particles that make up butter?

a. They are always quiet. Motionless.
b. They only move if we shake the piece of butter.
c. They are always moving.
d. They only move if other substances, the butter additives, push them.

About transformations of matter

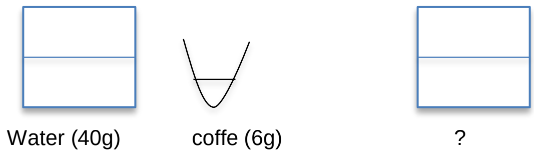
When we add a drop of ink to a glass of water, the drop makes a small stain. If we leave the glass at rest we notice that after a while the water will be totally dark. Why do you think this happens?

a. The ink particles are introduced inside the water particles.
b. The water particles dye with the ink and change color.
c. The paint particles break and release a water-staining substance.
d. The particles of the two substances move and mix together.

About conservation of mass in a mixture

The drawing shows a cup containing 40 grams of water and a container with 6 grams of instant coffee. If we put the coffee in the water and stir until it dissolves completely, we get a dark colored solution. What do you think will be the mass of the contents of the glass now?

a. 40 grams.
b. A value between 40 and 46 grams.
c. 46 grams.
d. More than 46 grams.



The activities, with the conceptual cores and levels of representation considered, are presented below, in addition to the objectives, strategies and concepts employed in each of the four meetings (sections) held with the students:

Section 1

Core concept: Matter as something discontinuous.
Representational Level: Macroscopic and symbolic.
Activities: storytelling - "Bubbles in Maria Clara's life ", with subsequent interview to diagnose students' conceptions; Study of a video about the water cycle in nature; Experimental activity: air expansion.
Objectives: Enable students to: a) Explain their notions about a process involving a change of physical state (boiling water) and a process involving a chemical transformation (production of CO_2 when an effervescent tablet is placed in water); b) Analyze changes of the physical state of water, differentiating the macroscopic and symbolic levels in the same study situation; c) Explain their ideas regarding a practical activity in which the volume occupied by air increases due to an increase in temperature.
Instructional Strategies: Counter suggestion; Explanation using the symbolic level to represent the macroscopic level; Problem solving.
Concepts: Physical states of matter; Transformations of the physical state of matter; Chemical reactions; Variation in the volume occupied by air as a function of temperature variation.

Section 2

Core concept: Matter as something discontinuous.
Representational Level: Macroscopic, symbolic and submicroscopic.
Activities: Asking questions or exposing ideas related to the previous meeting; Analysis of a video to study how a hot air balloon works; Study of compression and expansion of the molecules in the propane gas cylinder that is used to heat the air that inflates the hot air balloon; Analysis of other students' drawings with representations in the submicroscopic level.
Objectives: Resume ideas or questions related to the previous meeting; Know, from an everyday situation, the corpuscular kinetic model of matter; Re-elaborate explanations for the last activity performed in the previous meeting, using what was understood about the corpuscular kinetic model of matter presented; Elaborate explanations for an everyday situation considering the level of submicroscopic representation; Evaluate representations that indicate different understandings about the corpuscular model of matter.
Instructional Strategies: Explanation of ideas; Explanation using the symbolic and submicroscopic levels to represent the macroscopic level; Problem-solving; Extra class exercise.

Concepts: Variation of the volume occupied by air as a function of temperature variation; Variation of the volume occupied by propane as a function of the pressure variation.

Section 3

Core concept: Matter as something discontinuous; Conservation of unobservable properties.
Representational Level: Macroscopic and symbolic.
Activities: Asking questions or exposing ideas related to the previous meeting; Resumption of the example of the hot air balloon to analyze the combustion of propane; Resumption of a fact (chemical reaction) of the story told in the first meeting: Effervescent tablet.
Objectives: Resume ideas or questions related to the previous meeting; Analyze, by means of chemical equations (symbolic), information that characterize chemical reactions; Compare physical transformations and chemical reactions through the symbolic, recognizing the conservation and non-conservation of substances; Compare the macroscopic and symbolic levels in situations involving chemical reactions, seeking to identify differences between what is perceived by the senses and the representation model used in chemical language.
Instructional Strategies: Explanation of ideas; Explanation based on questions organized in an exercise; Counter suggestion and problem-solving.
Concepts: Chemical reactions: nonconservation of substances; Interaction between substances; Conservation of the number of constituent particles of substances; Comparison between physical and chemical transformations.

Section 4

Core concept: Matter as something discontinuous; Conservation of unobservable properties.
Representational Level: Macroscopic, symbolic and submicroscopic.
Activities: Asking questions or exposing ideas related to the previous meeting; Analysis of a computer software animation in which a representation of the submicroscopic level to a chemical reaction is presented; Experimental activity: Dissolving a tablespoon of sugar in a glass of water; Experimental Activity: Using barium hydroxide with sodium carbonate to conduct a precipitation reaction.
Objectives: Resume ideas or questions related to the previous meeting; Develop a representation of a chemical transformation in the submicroscopic level; Understand the possibility of reversibility in chemical transformations; Elaborate representations (symbolic and submicroscopic) for a dissolution; Understand the conservation of mass during physical and chemical transformations; Use information about symbolic and submicroscopic levels to differentiate the concepts of mixing and reacting; Compare information about macroscopic and symbolic levels in a chemical reaction; Evidence the non-conservation of substances during a chemical reaction, in addition to the conservation of matter.
Instructional Strategies: Explanation of ideas; Explanation relating the macroscopic, symbolic and submicroscopic levels; Problem-solving.
Concepts: Chemical reactions: non-conservation of substances, interaction between substances, conservation of the number of constituent particles of substances, reversibility, conservation of mass; dissolution of a solid into a liquid: conservation of substances; Comparison between physical and chemical transformations.

Data Analysis

In this way, it was possible to evaluate the changes produced by the proposed educational intervention (pre and posttests), as well as to perform content analysis of the results obtained, a methodology that allowed the Microgenetic Learning Analysis (Parnafes & diSessa, 2013), given the need for extended open, and careful consideration data. In addition, data collection to discover categories not previously determined work best during open and extended consideration of data.

The methodology employed to analyze the results obtained in the TLP (second stage of the process) (was content analysis (Bardin, 2009). The corpus of the analysis consists of the transcripts of the teacher students conversations and the written material produced by the students in the four meetings, in individual interviews. Thus, the qualitative analysis of content made it possible to verify the uniqueness of the elements presented, considering the variations identified in the explanations elaborated in each section, by each student, without the previous determination of categories. The parts of the dialogues and written explanations, always with open questions, were isolated (inventory) and organized the record units so that each student's individual theories could be identified, which condense and highlight the information provided by the analysis. That is, results were evaluated considering the improvements or the maintenance of the theories proposed by the students, from the conceptual nuclei and the levels of representation worked, as non-frequency indicators susceptible to inferences. These theories will be presented in tables arranged for each section (meeting). They allowed the detailed diagnosis, in a descriptive way, of the learning process presented by students which means operated throughout the process, showing the knowledge in transition for each student, in a given period of time. It is possible to find, in the same table, different ideas presented by students for the same process, because the activities were organized so that students could compare situations and re-elaborate explanations during interactions with the teacher.

RESULTS

The analysis of the results is organized in two parts. First, the results of the changes produced by the educational intervention and verified through the pre and posttests (Figure 2) are presented; the questions are presented in groups according to the contents involved, just like in Table 1. Next, the detailed analysis of the conceptual changes operated by the students is presented.

Pre and Posttests

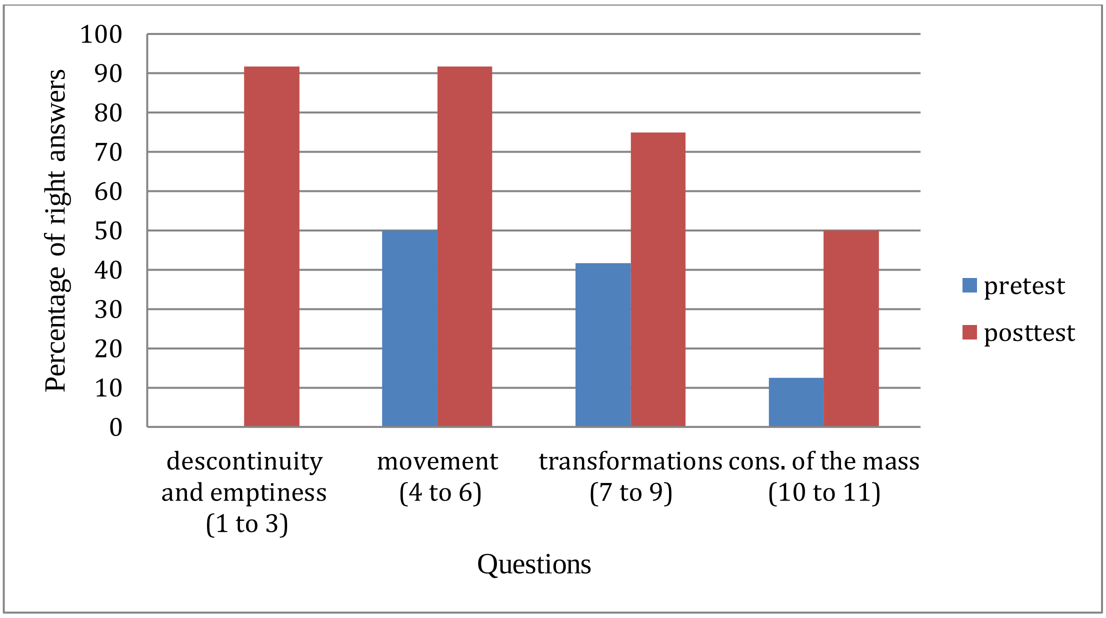


Figure 2 - Graph showing percentage of correct answers in pre and post-tests

Results show that in the first group of questions (1,2 and 3, about discontinuity and emptiness) students did not consider the idea of discontinuity of matter and emptiness between particles of solid, liquid and gaseous substances, opting mostly for the alternative that corresponds to the understanding of matter as something continuous. No students chose the correct answer, whereas in the posttest, for the same group of questions, there were more than 90% of correct answers.

For the second group of questions (4, 5, and 6), which dealt with the intrinsic movement of particles in solid, liquid and gaseous substances, initially half the students scored the correct answer and the other half chose the options that indicated the movement of particles as a result of the action of an internal or external agent. In the posttest, the success rate increased to more than 90%.

When interpreting the different transformations that matter can go through (questions 7, 8 and 9), the four students indicated 41.7% of correct answers in the pre-test, with most of the incorrect answers indicating the transmutation of matter as a valid answer. In the posttest, the success rate increased to 75% and the other responses attributed macroscopic properties to the particles.

In questions 10 and 11 students had to choose the answers that best represented what happens to the amount of mass of the substances during dissolution and a chemical reaction. The percentage of correct answers in the pre-test was 12.5%, so that in all other answers, 87.5% of the students indicated mass increase in the dissolution process and decrease in the chemical reaction. The percentage of correct answers increased to 50% in the posttest, that is, half of students' responses still did not consider the conservation of the matter in the processes presented.

Microgenetic Analysis of Learning

A detailed analysis in four sections is now presented, so as to allow a better understanding of the microgenesis of the changes observed.

Section 1:

As previously mentioned, in the first meeting three activities were held. The first activity was a storytelling presenting two distinct situations: boiling water and carbon dioxide production from an effervescent tablet placed in water. The intention was to make the students explain their theories about those phenomena, so that it was possible to see whether or not they differentiated a change of physical state (the main theme of meetings 1 and 2), and a chemical reaction (theme to be deepened in meetings 3 and 4), using counter suggestion. The second activity, specifically, addressed changes in the physical state of water, in relation to the macroscopic level (as observed by the sense organs) and the submicroscopic level (through equations such as $H_2O_{(s)} \longrightarrow H_2O_{(l)}$). The third one, the students were asked to propose explanations for an experimental activity in which it was verified the increase in the volume occupied by air due to the increase in temperature.

This way, the diagnosis of ideas presented by the students (Table 2) in activities in which they had to express, both in writing and verbally, their understanding about the facts under analysis, demonstrated that, just like in the pretest, students did not know or did not use the corpuscular model of matter, and based their explanations only on what is perceived at the macroscopic level.

Table 2 - Implicit theories presented by the students during the activities of the first meeting.

Students	Individual theories presented in the first meeting
Bento	-Proposes that the air presents characteristics similar to those of solid substances; -Indicates the production of bubbles as indicative of boiling; -Adopts the hypothesis of the decomposition of water into two gases to explain the appearance of bubbles in the water; -Considers the CR as something different from the boiling process, but says he cannot explain it.
Laura	-Proposes that, upon heating, the air changes its physical state, appearance and increases in quantity; -Indicates that water changes of physical state because it produces bubbles, but cannot explain what change of physical state means; -Considers the CR (production of gas) as the dissolution of a solid in water.
Leila	-Concedes the air non-material features; -Indicates that the bubbles produced in the ebullition of water correspond to the air present in the liquid that is modified when heated; -Uses the hypothesis of the decomposition of water into two gases to explain the appearance of bubbles in the water; -Says she had never thought about the effervescence of the tablet (CR) and, for this reason, cannot explain it.
Nina	-Proposes that the air has characteristics similar to the ones of solid substances; -Considers air as synonymous with oxygen; -When analyzing the expansion of the air as a result of an increase in temperature, disregards the air, justifying the increase in volume by a vaporization process of small water droplets present in the system under consideration; -Indicates that bubbles are produced because water temperature reached 100 ° C and began to boil; -Considers the CR (production of gas) the result of the contact of something solid with water.

Regarding the boiling water (change of physical state in which matter and substance are conserved) when the counter suggestion strategy was applied to motivate students to elaborate on their own arguments, Laura and Nina insisted on their initial hypotheses that there was a change of state, although they could not explain what had happened to the water during the transformation. Leila and Bento modified their initial explanations and chose the possibility that water was decomposed into two gases (oxygen and hydrogen), which, according to them, seemed more logical. Therefore, it can be noted that they felt safer to choose an answer reasoned by a language more similar to the one used in their chemistry classes, 'more scientific'.

Bento and Leila, did not provide any explanations for the chemical reaction (tablet effervescence in water) in which there is formation of a gas, with the justification that they did not know how to explain it. Laura, on the other hand, considered it to be a dissolution process, while Nina said it was a result of the contact of the tablet with water.

As in the study developed by Liu and Lesniak (2006), in which students could use scientific vocabulary (most of them incorrectly) they had learned in their classes, the idea is to identify the students' implicit theories about the facts to later problematize them, but in the majority of cases lacked conceptual understanding, it was possible to observe the lack of understanding regarding the concepts used in the explanations, such as physical state transformation, ebullition, dissolution and boiling. Students used these terms as if they were sufficient to account for the explanations, although they were not sure about what they meant, which can be seen in Laura's explanation to the idea of boiling water:

(Laura) Why did it change its state? It was cold and will heat up, I think it is this. (Teacher) Which state? Have you studied this in science classes? (Laura) Yes, I have, but I do not remember.

Students based their explanations exclusively on what is noticeable; they also had difficulties analyzing facts related to gaseous substances (air bubbles produced in boiling and tablet effervescence), characterizing them as solid or simply disregarding them. Bento and Nina indicated that, with heating (in activity three) all the air moved from one place to another. The same explanation has been found in research carried out by Benlloch (1997). According to this author, this demonstrates that the air is being analyzed according to displacement characteristics like the ones perceived in solid materials. Conversely, Leila's explanation disregarded air. She believes that water steam, which she calls 'air', which is apparent (moving from bottom to top in the container with hot water), can pass through the walls of a container, such as the bottle used in the experiment. In this case air is considered to have characteristics of physical rather than material entities (Benlloch, 1997).

According to Barker (2000), this is a problematic issue for students, to the extent that some of them find it difficult to accept gases as "substances" and believe they have no mass, or confuse mass and density. In addition, the author indicates that poor models of particles of matter contribute to increase students' difficulties because when failing to actually understand what happens at the molecular level, students naturally make up their own theories.

Section 2:

In the second meeting (Table 3), the students were presented to the corpuscular model of the matter through a video that showed the observation of the operation of a balloon ride, focusing on the increase in the volume occupied by air after heating and also on the behavior of propane gas stored under pressure in a cylinder. These facts indicate matter as consisting of particles which are in continuous motion and separated by empty spaces. It was proposed that the students take up what was observed in the last activity of the previous meeting in order to re-elaborate their explanations, as well as they were asked to evaluate drawings, supposedly made by other students, to represent the particles that make up the air in a situation where there is variation in pressure in a closed system. Following the presentation of the corpuscular model of matter, students had to analyze a specific situation through the comparison between macro, symbolic and submicroscopic levels of representation. It was observed that they considered the discontinuity of matter and the empty spaces between particles, but disregarded the intrinsic motion of the particles, and presented some confusing ideas as a result of the mixture of individual theories and the new concepts in submicroscopic level.

According to Gómez Crespo (2008), the understanding of the intrinsic motion of particles is one of the conceptual nuclei that creates the greatest difficulty for students, and this is related to how matter is perceived at the macroscopic level (in most cases in rest). The outcome of the second meeting corroborate Gómez Crespo's statement, as the four students presented in their explanations the understanding that matter is made up of particles, and three of them considered the empty spaces between the particles, however, the understanding that the particles are in continuous motion was not evident in the students' statements.

Table 3 - Implicit theories presented by the students during the activities of the second meeting.

Students	Individual theories presented in the first meeting
Bento	-Uses the corpuscular model of matter to assess the behavior of a gas under pressure, indicating that there are empty spaces between the particles and that these spaces are reduced under pressure; - Disregards the continuous movement of particles.
Laura	-Uses the corpuscular model of matter to assess the behavior of a gas under pressure, indicating that there are empty spaces between the particles and that these spaces are reduced under pressure; -Disregards the continuous movement of particles.
Leila	-Uses the corpuscular model of matter to assess the behavior of a gas under pressure, indicating that there are empty spaces between particles and that these spaces are reduced under pressure. -Indicates that, under pressure, particles collide and are closer to one another. -Treats energy as substance.
Nina	-Uses the corpuscular model of matter to assess the behavior of a gas under pressure, indicating that there are empty spaces between the particles and that these spaces are reduced under pressure; -Particles stand still when under pressure.

Leila, for example, did not change her opinion that there is air between the gas particles, which may indicate that, for her, air corresponds to emptiness. She used the concept of energy as identical to the concept of substance:

When the teacher explains the model of particulate nature of matter and mentions the empty spaces between the particles, (Leila) Between the particles there is air! (Teacher) No, they are empty spaces! The air consists of several substances such as oxygen and nitrogen […] in advance, when the teacher asks the student to think about the task done in the previews meeting, in which she had affirmed that the air could run through the walls of the recipient, *(Leila) So, in the bottle, its heat went inside these empty spaces that lie between the molecules! (Teacher) We may think so. Well, the water particles that are outside the bottle cannot go into the bottle because the plastic acts as a barrier that does not allow it; what can be transmitted is energy, in the form of heat. (Leila)So, the air did not come in? (Teacher) The air was already inside the bottle, remember? So, what do you think may have heated it? (Leila) That the bottle warmed up and the heat went inside it, and the hot air reached the balloon (Teacher) And what happens to the particles that make up the air and receive this energy that was transferred? (Leila) They expanded in space*.

Leila's statements showed a mixture formed by implicit theories presented in the first meeting and her new information presented by the teacher in explaining the corpuscular model of matter. In these situations, according to Pozo and Gómez Crespo (2009), the teacher should propose activities for the student to start a process of differentiation between what she believed and what was proposed. Since, the new theory regarding corpuscular model of matter can only be understood if it differs conceptually from the previous model, for example, continuous conception of matter. Therefore, it is necessary for the student to construct new conceptual structures in order to rewrite his interpretations within the more complex structures.

Section 3:

In the third meeting (Table 4) when students were asked to make comparisons between the information in the symbolic and macroscopic levels for processes involving chemical reactions and changes of physical state (this activity showed the students the chemical equation that represents propane gas combustion ($C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$) - by resuming the video from the previous meeting - and the equations used to represent the changes in the physical state of the water from the first meeting, it was possible to perceive difficulties in the interpretation of symbolic information. When the change of physical state and the chemical reaction were compared in the symbolic level, Leila and Laura indicated the physical states of substances (represented by S-solid, L-liquid and G-gas in the chemical equations), as common features between the two processes, that is, these were the only chunks of information they could interpret, failing to identify the conservation or non-conservation of substances in the processes. Bento and Leila's misconceptions regarding the representation of atoms and substances also point to the lack of meaning of the symbols.

Table 4 – Implicit theories presented by the students during the activities of the third meeting.

Students	Individual theories presented in the first meeting
Bento	-Identifies that both CR as the CPS have a before and an after; -Characterizes the chemical equation as a mathematical account (symbolic); -Confuses atoms with substances (symbolic); -Does not understand information of the chemical equation that indicates the formation of new substances (symbolic); -Speaks of energy as having the same characteristics of substances; -Evaluates the appearance of bubbles in the CR as a CPS of a solid due to the way it is when in contact with a liquid;
Laura	-Uses the physical states of substances as a criterion to compare the chemical equations of a CPS and of a CR (symbolic); -Evaluates CR as a CPS (gas to liquid), pointing to the conservation of the number of atoms; -Does not differentiate macroscopic and symbolic levels in CR and CPS; -Indicates production of gas as a result of CR, but cannot explain what a CR is.
Leila	-Uses the symbolic level to indicate the non-conservation of the substance and the conservation of matter in a CR; -Uses the physical states of substances as a criterion to compare the chemical equations of a CPS and of a CR (symbolic); -Confusions between atoms and substances (symbolic); -Does not differentiate macroscopic and symbolic levels in CR and CPS; -Considers the CR a mixture; -Speaks of the bubbles produced in the CR, apparent at the macro level, as no gas.
Nina	-Perceives the conservation of substances in the CPS; -Presents an additive view of CR, with conservation of the number of atoms; -Differentiates what is perceived and what is represented in the symbolic level in the CR and CPS; -Confuses concepts such as conservation, modification of atoms/substances (symbolic); -Compares information of macro and symbolic levels for the gas that is perceived.

Their failure to understand the information provided in the symbolic level (chemical equations) when they had to interpret the chemical reaction process shows that students continue employing ideas based on the macroscopic level, a situation that does not allow them to consider the interaction and non-conservation of the substances involved. Being aware of these characteristics presented by students, the teacher can elaborate activities that allow them to understand that the representation through symbols is one of the possibilities, widely used by chemistry, to understand the processes under study, that is, as proposed by Johnstone (2000) teaching and learning processes should gradually move the student inside the triangle (with the three vertices - macroscopic, symbolic and submicroscopic levels) so that he can explain, for example, a chemical reaction at macroscopic levels (with the description of what is perceptible), the submicroscopic (with the particle model) and the symbolic (with the chemical equation).

In this meeting, the chemical reaction presented in the storytelling of the first meeting was resumed, and, initially, the students were invited to resume their explanations and also to evaluate the explanations supposedly elaborated by other students (counter - suggestion), then, the representation of the process at the symbolic level ($NaHCO_{3(aq)} + H_3C_6H_5O_{7(aq)} \longrightarrow NaH_2C_6H_5O_{7(aq)} + H_2O_{(l)} + CO_{2(g)}$) was exposed to the students and asked to evaluate which of the previous hypotheses would best explained the represented process.

Nina, when explaining the chemical reaction, presented the idea that the substances came together to form a single substance,

After the counter-suggestion, (Nina) I think it is the third one, just like I said, it is the best option because you put it (tablet) in the water and then there is it, the liquid water and the gas. (teacher) And this *substance that was here, did it exist before, is it equal to any of the reactant substances? (Nina) No, it joined the two.*

According to pozo and Gómez Crespo (2009), many students comprehend the chemical reaction as a process in which initial substances are added to obtain a product, which corresponds to the sum of the reactants, a fact that shows difficulties in interpreting change as a more complex interaction process, where conservation comes from an exchange process, in which some win and some lose. Also, for Pozo and Gómez Crespo (2009), high school students do not differentiate changes that occur in a solution and in a chemical reaction, with interpretations in terms of interaction between substances to obtain a different one, or conservation of the substance, even if it changes the aspect.

Leila stated that a chemical reaction corresponds to a process of mixing substances and Laura and Bento explained the chemical reaction as a change of physical state. Bento, when comparing a change of physical state to a chemical reaction, which he was not able to explain in the first meeting, proposed it is a change of physical state resulting from the features of the effervescent tablet:

(Teacher) Now let's think a little about the effervescent tablet: I remember you said "I do not know what might have happened". And now, have you got any idea about what formed those bubbles? (Bento) Something like that, I think it's because of the way it is, when we put the tablet in the water, this changes its state.

Similarly to what happened to Leila in the previous phase, in the third meeting Bento uses the concept of energy as similar to the one of substance. According to Finegold & Trumper apud Barker (2000), student responses often suggest that energy is made of something. Still, habituated to the use of colloquial expressions such as “waste of energy”, “energy sources” among others, students have difficulties in differentiating the scientific (abstract) concept from their implicit theories built on the experiences outside the school environment (Pozo & Gómez Crespo, 2009).

Section 4:

In the fourth meeting (Table 5) it was perceived that when performing the first analysis of the experimental activity (the dissolution of a spoonful of sugar in water as a process in which matter, mass and substances are preserved), students use what they can observe visually (macroscopic) as the basis for their explanations and, as they are questioned and asked to have a more detailed look at the processes, they resort to models at the symbolic or submicroscopic level to redraft their theories, i.e., they begin with the elements they are used to, which have been used for years, and then gradually integrate the new concepts exposed during the meetings.

Table 5 - Implicit theories presented by the students during the activities of the fourth meeting.

Students	Individual theories presented in the first meeting
Bento	-Considers dissolution based on the macro, as a fact in which nothing happened; -Indicates the conservation of mass and matter, and the non-conservation of the substance in CR; -Identifies the conservation of mass in dissolution; -Perceives the conservation of substances in dissolution as a criterion to differentiate it from the CR.
Laura	-Sees dissolution as a CR in which the substances came together and formed a new substance; -The reversibility, the formation and release of gas are the criteria used to distinguish a dissolution from a CR; -Indicates the increase in matter by the formation of a precipitate in CR; -Characterizes CR as a process of separation of particles; -Indicates that during the CR number of atoms remains the same, but cannot interpret the Chemical Equation (symbolic) and check it; -Does not differentiate macro and symbolic in CR. -Identifies the conservation of the substance in the dissolution (macro and symbolic)
Leila	- Interprets CR as dissolution; -Treats dissolution as the sum of two substances; -Confuses the conservation of mass and conservation of substances; -Perceives the conservation of matter in CR; -Considers the appearance of the precipitate as a CPS;

Students	Individual theories presented in the first meeting
	-Does not differentiate the macro and the symbolic; -Represents the conservation of substances in solution (submicroscopic).
Nina	-Speaks of dissolution as a CR in which the particles change position. -Identifies the conservation of mass, matter (reorganization of atoms) and non-conservation of the substance in the CR; -Uses the information in the symbolic level to predict what will happen during the CR in the macro level; -Perceives the conservation of the substance in dissolution as a criterion to differentiate it from the CR.

The four students had different ideas during the development of the activities, according to the understandings they were able to elaborate along the four meeting. However, the conservation of matter in the dissolution process (submicroscopic level) was indicated by all of them. As mentioned before (in the presentation of the four sections), the first activity performed in this meeting was the analysis of an animation (computational software) where a chemical reaction is represented at the submicroscopic level, highlighting the interaction between the reagents and also between the products (in a closed system) with the possibility of reversibility of some chemical reactions, indicating the reorganization of atoms in the formation of the products. This situation was used to request that students compare chemical reaction and the dissolution of sugar in water, aiming to differentiate the two processes. Also, as a last activity, another chemical reaction was used to analyze the macroscopic (experimentation) and symbolic (chemical equation) levels with formation of a solid (precipitate).

Laura based most of her explanations on the macroscopic level, showing she needs more time and a greater number of activities to be able to understand concepts that other students can already use properly. The ideas that a chemical reaction is a process of separation of particles, and that when a precipitate is formed there is an increase in the mass of the products demonstrate she failed to understand the conservation of matter. Possibly, the difficulty in perceiving that the changes observed in chemical transformations are the result of the reorganization of atoms leads students to use inadequately the idea of conservation of mass, often employed in relation to other phenomena, such as changes of physical state and dissolutions. Many students tend to predict that a precipitation reaction causes a mass increase in the system because a solid was formed, and solids are heavier than liquids. Students who develop this kind of idea are likely to confuse density with mass (Mortimer & Miranda, 1995).

Leila and Nina, who in the macroscopic level assessment had proposed that during the dissolution new substances would be formed, had difficulties differentiating a process of dissolution from a chemical reaction. However, they were able to restate their arguments. Leila, for example, explained important conceptual confusions in the symbolic level to analyze the chemical equation, did not indicate the non-conservation of substance in the chemical reaction and proposed that the formation of the precipitate occurred due to the change of physical state of a substance. Nina interpreted the information in the symbolic level to predict what would happen in the experimental activity, and used the notion of conservation and non-conservation of substances as a criterion to differentiate dissolution from chemical reaction:

(Nina) Will a solid be formed? (Teacher) Is the equation confirming this idea? (Nina) It is because these two aqueous will form a solid and another aqueous (Teacher) Oh, then it will! (Nina) Let's see if I was right about something. [When she answers the question about how she would verify the conservation of matter in the chemical equation]: *I will not say anything, because I know they just reorganize themselves! In the third [asks which of the substances in the equation is the precipitate] is this one here, isn't it?* (pointing to the formula of the precipitate)*, I said it before! (Teacher) That's right, you had already identified it before I asked. Why is it a chemical reaction and not a physical transformation or dissolution? (Nina) Ah, because other substances were produced.*

CONCLUSIONS

The results of the analysis of the students' constructions during their participation in the activities proposed by the TLP point to considerations that can help broaden or deepen the reflections and planning of actions for those who wish to propose improvements in the teaching of chemistry in high school.

First, it should be noted that the qualitative analysis of the paths taken by four students evidence the complexity involved in the processes of teaching and learning fundamental concepts to understand chemistry theories that will be studied throughout the three years of basic instruction.

In relation to the first question raised by this work, "What are the students' implicit theories at the beginning of high school?", the collected data show that as in relation to the corpuscular model of matter, as to the conservation of the proprieties non observable, and concerning the first objective (getting to know the students' ideas at the beginning of their Chemistry studies), it was found that the models initially presented by the students were based mostly on what can be perceived, i.e., the macroscopic, and that they did not use the models studied in science and / or chemistry classes. In the first meeting, the four students described what they could visually perceive, and did not present any model of submicroscopic or symbolic levels to explain the behavior of the particles at the different activities explored. In the other meetings, whenever a new situation was presented, the students indicated their understandings about the facts under studies from their implicit theories based on different comprehensions from those scientifically accepted, as it was possible to perceive from the dada presented in 2,3,4, and 5.

However, it was possible to see a considerable progress in the use of the models proposed, both in the arguments developed by students during their participation in the TLP and in the comparison of the results obtained in the pretests and posttests. When analyzing students' conceptual changes, which was the objective presented in the second question proposed in the investigation, in relation to the first conceptual core studied, the corpuscular model of the matter, Bento and Nina indicated the expansion of air as if it behaved like a solid, that is, as if the air came out of a container and occupied the balloon (therefore it increased in volume). In the second meeting, after the model had been studied, both were able to explain the behavior of the air considering the discontinuity of matter and the increase of empty spaces between them, by differentiating their initial ideas from the model employed by chemistry. Laura, who, at the first meeting, explained the increase in air volume by heating as a result of the change in the physical state of the gas, also used the model of empty spaces between particles to characterize the change in volume at the second meeting. Leila, who explained the idea of air having non-material characteristics, was able, later, to indicate the behavior of the particles that constituted air, without understanding what the empty spaces would be. It is noteworthy that the four students did not use the concept of intrinsic particle motion to complete the corpuscular model of the matter studied. However, considering this in just two meetings, it is important to underline that the conceptual changes indicated the need to continue the use of the model throughout high school studies, in chemistry classes, to gradually promote reflections of representational re-description of some knowledge in order to allow students be aware that certain (scientific) forms of knowledge have greater representational power than other simpler forms of knowledge, which undoubtedly have great cognitive functionality (Gómez Crespo, 2008). It is also important to underline that the results of the pre and posttest, as one more source of information about the conceptual changes made by students in questions 1 to 6 also showed that the four students started to consider the alternative corresponding to the corpuscular model of matter as correct in the majority of the answers.

As for the second conceptual core addressed, the conservation of unobservable properties, more specifically, in processes where there is no formation of new substances (physical state changes and dissolution), and others in which substances are not conserved (chemical reactions), it was possible to realize that each student became aware of his implicit theories and made differentiations in different ways. The results obtained in the comparison between the pre and posttests showed that there is a considerable advance in the choice of the scientifically accepted answer by the students (questions 7,8,9,10 and 11), providing one more source of data regarding the comprehension. In the process of learning microgenetic analysis, student Bento, initially, considered valid the idea that boiling was a process of substance decomposition (first meeting), and indicated that he did not understand the information of the equations that represented the state changes and chemical reactions, characterizing them as mathematical accounts (meeting three). However, in the fourth meeting, he used the conservation of the substance as a criterion to differentiate the dissolution processes and the chemical reactions studied, showing that through the chemical equations that represent the reactions it is possible to verify the conservation of the mass and of matter. Laura and Leila, who initially showed that they understood chemical reactions as changes in physical state and dissolutions (first and third encounters), and when asked about the differences between the implicit theories indicated and the scientific models studied, they said, they could not explain chemical reactions, they understand the conservation of the substance in the studied dissolution and the conservation of the matter in the chemical reactions, but still showed to misunderstand scientific concepts about the conservation of the mass, and about the differentiation of the dissolution and the chemical reactions, including the non-differentiation between the symbolic and macroscopic levels. Student Nina, who failed to use a model to explain the chemical reaction, at the first meeting, and proposed the idea of adding substances to explain the same process at the third meeting, explained the conservation of matter, mass and substance in the dissolution process, by indicating the conservation of the substance as a criterion to differentiate it from the chemical reactions under analysis, proposing the formation of a solid product in the last chemical reaction studied from the previous analysis of the equation that represented the process to be performed experimentally afterwards.

It is verified, thus, in the detailed study of the paths taken by each student, that there are differences in the time required to learn the concepts under study and thus, to rearrange them in different representational levels, that is, this investigation showed that the theoretical restructuring, the explanation of the implicit theories, and finally the hierarchical integration will happen differently for each subject, paths indicated by Pozo and Gómez Crespo (2009) in the proposition of the proposed conceptual change. Thus, the analysis of the collected data allows answering the third question.

"How do conceptual changes occur during each student's learning process?", The microgenetic analysis of learning revealed that even when students return to their usual ways of interpreting situations at the beginning of each problem, trying to find in the macroscopic level the answers they consider appropriate, they make use of other levels of representation during the development of the activities, with a gradual growth in the understanding and use of new information.

Nina's case was particularly noteworthy; her re-description showed the greatest change of her representations in the new approaches proposed, in such a way that her explanations for the phenomena analyzed gradually showed, since the beginning of each activity, in different contexts, her attempts to assimilate the scientific theories proposed, unlike the other students who, when stating their ideas at the beginning of most of the activities (in a situation with a different context than those previously addressed), still used aspects of the macroscopic level as the sole basis for their arguments and only after the problem-solving activities proposed were able to re-elaborate their interpretations. Difficulties related to the context in which the activities are presented were reported in studies (Adadan et al., 2010; Tao & Gunstone, 1999) that analyzed students' process of conceptual change during the process of learning scientific concepts.

The detailed follow up of how conceptual changes occurred, which corresponds to the third objective of this study, showed that it was also observed that in most of the situations in which students elaborated answers trying to contemplate some principles of scientific theories, their interpretations presented a mix of ideas, grounded on the macroscopic levels, and notions of the symbolic and /or submicroscopic levels. According to Pozo and Gómez Crespo (2009), when the amount of microscopic responses increases, they are usually accompanied by other interpretations based on the students' implicit individual theories, in a way that the resulting representation is confusing due to the uncritical and superficial assimilation of the corpuscular model, that is, students mix information provided in the instruction with their own preconceptions.

Corroborating Cooper et al. (2013), it is important to emphasize that students build different sets of explanations and conclusions when they participate in a particular activity proposed by the teacher; therefore, it is essential to pay close attention to the changes that happen in the explanations given by the students to be able to propose problems that allow them to move towards a greater understanding of the scientific models proposed; the understanding of the chemical theories is a process that may take different times and go through different paths, according to what students can grasp from the class activities, and the feedback given by the teacher about their difficulties and improvements, requires constant evaluation because "(…)when students produce accurate answers, learning is not completed, nor durable, but rather is just taking its first steps" (Potvin, Suriol & Riopel, 2015).

Thus, it can be concluded that the subjects involved in the teaching and learning process should rethink their attitudes towards what traditionally occurs in the classroom, because in proposals like the one presented here, students are no longer simply reproducing what was transmitted by the teacher; they become active knowledge builders. When students' concern about whether or not they were responding correctly to the proposed activities was diagnosed.

It is therefore proposed that the results obtained in the TLP allow the suggestion of alternatives that can be incorporated into other practices in order to promote improvements in the teaching and learning of chemistry, emphasizing the idea that it is of paramount importance that chemistry instructors provide students with means for a conceptual change, considering processes to differentiate and integrate everyday and scientific knowledge in different levels of representation (macroscopic, symbolic and submicroscopic).

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