Re-Elaboration of Chemical Concepts by Chemistry Undergraduate Students Doing Initial Teacher Training in a High School: A Contribution to the Historical-Cultural Perspective

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Abstract: We investigate Undergraduate students in their Initial Training for Teachers of Chemistry within a collaborative framework involving the University of Sao Paulo and a public Elementary and High School. We analyze how Undergraduate students revisit, re-elaborate, and recontextualize academic knowledge within the scope of their pre-service teacher education program (PIBID). During their training, the Undergraduate students engage in both pedagogical and discipline-specific activities to improve their teaching skills. University mentors aid the training students, and teachers of chemistry working in the public Elementary and High School contribute by sharing their expertise. To answer the research question: *"How do Undergraduate students attending the pre-service education program in Chemistry re-elaborate concepts of chemical equilibrium for secondary education?"* this study revisits and recontextualizes several distinct chemistry concepts for presentation in the High School classroom environment. To achieve our goal, we used the audio recordings of planning and assessment meetings held at Department of Chemistry, Faculty of Phylosophy, Sciences and Letters of Ribeirao Preto, University of Sao Paulo. To date, the PIBID groups have met seven times, and nine sessions have been taught at the pilot school. The theoretical foundation of the present work is based on the historical-cultural perspective and on the Theory of Activity. Eventually, this project will contribute to the discussion and improvement of pre-service teacher education in Chemistry.

Keywords: Theory of activity, language, chemistry, pre-service teacher education program.

Introduction

The present paper proposes investigating Initial Training for Teachers of Chemistry under a collaborative University-High School framework. The PIBID group, a pre-service training initiative of the Department of Chemistry of the Faculty of Phylosophy, Sciences and Letters of Ribeirao Preto (FFCLRP), University of Sao Paulo (USP), supports this project funded by CAPES, a Brazilian Foundation that provides financial aid to Higher Education projects.

Created in 2007 by the Brazilian Ministry of Education and implemented by CAPES, the Institutional Program of the Teaching Initiation Grant (PIBID – *Programa Institucional de Bolsa de Iniciação à Docência*) aims to enhance the teaching profession and support undergraduate students from public Universities.

The aim of the PIBID is the enhancing of teacher training and its improvement for High School. The scholarship students participating in the project are awarded grants for their participation in activities developed by public Universities in partnership with public High Schools. Thereby, students are introducing from the beginning of their academic training to develop didactic and pedagogical activities under the guidance of an University mentor and a High School teacher.

Other PIBID proposals are the improvement of the academic actions for the training of teachers with undergraduate education for High School; the introduction of the undergraduate students in the daily life of public High Schools, the contribution for the valorization of teaching; the integration between University and High School; the participation of future teachers in methodological, technological and teaching practices experiences of innovative and interdisciplinary nature; the searching for overcoming problems identified in the teaching-learning process; the mobilizing of High School teachers as trainers of future teachers; and the contributing to the articulation between theory and practice necessary for training of teachers students (Ministério da Educação do Brasil, 2016).

The PIBID of the degree in Chemistry for Teaching of the FFCLRP was consolidated as a team in August 2012 and was based on Leontiev's Theory of Activity (1978) and the concept of Teaching Activity proposed by Moura (1992). In the PIBID context, the undergraduate students need to elaborate didactic activities on chemical contents to be carried out in a partner public High School. The central purpose of this project is to coordinate efforts to improve the quality of the Brazilian University by awarding scholarships to Undergraduate students. In this context, we aim to investigate how Undergraduate students in their Initial Training for Teachers of Chemistry re-elaborate concepts of chemical equilibrium, an emphatically studied theme in the discipline of chemistry, to teach them to High School.

The theme “chemical equilibrium” is conceptually complex and difficult to understand, so it has been the topic of numerous studies (Machado and Aragão, 1996; Milagres and Justi, 2001; Pereira, 1989; Sitanaka, 2001; Soares, 2001; Teixeira Júnior and Silva, 2009a, 2009b).

The Teacher Training Program adopted at USP in 2004 resulted in influential proposals for Undergraduate students attending Chemistry programs, including the Chemistry program offered at the Department of Chemistry of FFCLRP/USP. Normally, Undergraduate students start attending pedagogical disciplines as soon as they start the program, and Supervised Curricular Training (SCT) takes place in the fifth semester. The University mentors arrange the Teacher Training stage. However, this model fails to produce satisfactory outcomes: school-related issues such as language use, type of re-elaboration, applied didactics, and proper use of analogy are idealized and far from the actual classroom routine. Moreover, activities are planned in the pedagogical area available at the Department of Chemistry of FFCLRP/USP, so that High School Teachers end up having minor participation and little decision-making power along the process.

Given this situation, University mentors need to consider re-elaboration. The contents taught to Undergraduate students must eventually undergo pedagogical changes. Such re-elaboration would provide High School students with concepts aligned to the reality of their school, which is the central issue of the present work. Connecting chemical and pedagogical knowledge is mandatory. When Undergraduate students become Teachers of Chemistry, they cannot simply replicate what they learned at University in the High School environment (Schnetzler, 2000). In that case, from whom can Undergraduate students learn how to re-elaborate chemistry concepts? How can they teach the chemical contents? If the chemistry syllabuses of Undergraduate and High School programs are different, which chemical contents should these programs share?

Theoretical foundation

According to the technical rationality model, first theories have to be learned. Then, they can add instrumental value to learning to the extent that they are applied in solving practical problems. Such conception of "Teacher" is put forward in Teacher Training courses conducted under a "3 + 1" model. This model entails including all specific and pedagogical formation in the first years of the Teacher Training program, whereas internships occur at the end of the program. A number of authors have pointed out the theory-practice dichotomy in this Teacher Training program (Maldaner, 2000; Pérez-Gómez, 1992; Schnetzler, 2000; Schön, 1983).

Regarding Teacher Education as a research object, it is appropriate to ask the following questions: How do human beings learn? How do human beings develop? There are many answers to these questions, and scientific development notoriously contributes to the accuracy of the answers. Under the reference framework of historical-cultural perspective, we consider the Vygotskian assumptions, which emphasize the role that subject-environment interactions mediated by cultural artifacts play in enabling individuals to acquire historically built concepts. This perspective stems from the historical and dialectical materialism based on the Marxist philosophy. According to this line of thought, humans transform themselves when they transform Nature. This change creates the conditions for historical and social development to take place.

Soviet psychologists elected the concept of activity as one of the core principles of studies on psychic development. Understood as a dialectical unity, consciousness and activity are regarded as two key elements of historical-cultural psychology. According to Vygotsky (1984), Learning:

> [...] presupposes a specific social nature and a process through which children grow into the intellectual life.

Cognitive development derives from the relationship that subject builds with the natural and social environments. The environments are mediated by instruments and signs, such as language. Hence, Learning does not occur spontaneously. It is essential that the subject's conditions are culturally mediated through human social experience and not only through biological factors.

The Vygotskian premises observe the need to analyze processes within their development (Vygotsky, 2000). The training object comprises the process of conceptual re-elaboration that the chemistry students experience. Therefore, it is necessary to place the subject into motion first, so that the training object can be grasped. Language constitutes the principal mediating instrument of this theoretical basis in which the subject is active.

Vygotsky studied the theories and mechanisms through which a subject develops and is included in the social context. Human development should take an inward direction because the subject's immersion in the world is relevant. Thought and Language embody a dialectic unity, but they act as autonomous elements. In this sense, both word and thought must be understood as a process - not a thing. This process brings a movement of thought to speech and a movement of speech to thought with it (Vygotsky, 2009).

Subject-object and stimulus-response relationships are mediated by activity. Such arrangements depend on conditions, objectives, and means. All activities have a necessity as their primary condition. The main trait of human activity refers to its objectal character, which should be understood relationally before an object (real or achievable). Hence, the object becomes the subject's driving force. For instance, if a subject is "thirsty" and their need is to quench their thirst, they can only become active if the object "water" is available. According to Leontiev (1978, 1983), the necessity is materialized in the object, which becomes the purpose of the activity. The same is true regarding the learning activity.

Context and methodology

The present work leans on a qualitative methodology that relies on participant observation (Lüdke and André, 1986). The participant observation method is a crucial tool for research in Chemistry Education. Here, we use this method to analyze how PIBID Chemistry students are involved in the re-elaboration of Qualitative Analytical Chemistry (QCA) concepts. This analysis includes teachers working in public High School in the city of Ribeirao Preto - Brazil and the expertise of the University mentors that coordinate the project.

The process experienced by the subject constitutes our study base. In Minayo’s view (2010), "to understand" is the main verb of qualitative analysis. In this context, "understanding" refers to creating circumstances that exercise perception, taking each individual’s uniqueness and subjectivity into account. Each subject carries their own history which, along with their personal experience, is contextualized with the culture of other groups. Such arrangement ends up building the collective history. Understanding both the study group members and researchers is partial and unfinished. By understanding the language through social relations, one can notice the conflicting character of language and can grasp the contradictions of actions.

Our findings are based on meetings and lessons that took place on the following dates: August 15th, 2014; August 19th, 2014, and August 26th, 2014. The PIBID coordinator of the Teacher Training program and two school teachers (Chemistry and Biology teachers of a public school in the city of Ribeirao Preto, Brazil) participated in the meetings along with ten (10) PIBID students. The students were identified by the codes S1 – S10, without gender specification. The dialog was sequentially numbered in chronological order.

Results and discussion

The meeting started with discussion of the lesson plans that PIBID students had developed to teach chemical equilibrium. Transcription of the conversations and observations raised during the meeting follow as a preliminary analysis.

In the context of this discussion, the ten participating PIBID students shall be referred to as “S1”, "S2", and so on.

> 1.S1: I had planned to bring the concept (of chemical equilibrium) closer to their (the High School students) day-to-day lives. I thought of contextualizing, so I found a newspaper report on a hydrochloric acid spill into a lake describing how that event disturbed the system and messed with the equilibrium of the medium.
>
> 2.Coordinator: There is only one problem there... has anyone noticed it? (Silence in the room). What kind of substance is present during chemical equilibrium in aqueous solution?
>
> 3.S2: Weak ones.
>
> 4.Coordinator: Is hydrochloric acid weak?
>
> 5.S1: No.
>
> 6.Coordinator: So this was not a good example! Hydrochloric acid (the coordinator rises, goes to the board, and prints the formula HCl, followed by its ionization reaction in water, $HCl(aq) \rightarrow H+(aq) + Cl-(aq)$) ionizes completely when it is placed in water. When do we have a situation of chemical equilibrium?
>
> 7.S1: Well then! I also thought of using an example to illustrate that. I thought of a rope and many people pulling it on one end and many people pulling it on the other end! To maintain equilibrium, they would have to use the same strength on both end.
>
> 8.S3: There is also the treadmill case, which the Professor of Chemistry Teaching methods would always discuss with us: On the treadmill, you

walk onwards, while the floor of the treadmill goes the other way; you are in motion, but goes nowhere.

9.Coordinator: We are going to analyze each case. (The coordinator rises and draws two vectors of opposite directions, to represent a rope.) Let's see, considering a tug-of-war, the forces must be equal on both ends of the rope for equilibrium to exist.

10.S2: If there are fewer people on one end, they have to make more effort to maintain the position of the rope...

11.Coordinator: I have just written the CH3COOH ionization reaction on the board. Once again, I ask you: Do we have equilibrium here?

12. All: yes.

13.Coordinator: So, how can we define it? In chemical equilibrium, we have reacting species and products coexisting in solutiom. Which species coexist here? Students answer the question as it is written on the board: CH3COOH, H+, CH3COO-, H+ (from water dissociation), and OH- (from water dissociation).

14.Supervisor 1: Look folks, you must be especially careful with the examples that you use with your students because once you build a misconception, there's no time for remedy.

15.Coordinator: So, what can we conclude? Would the tug-of-war be a sound analogy for chemical equilibrium?

16.S3: No, because it is static.

17.Coordinator: That's right! The tug-of-war gives the idea of something stationary. What's more, the forces have to be equal for balance to be reached, which implies that or can lead to the understanding that the concentrations of the reacting species and products in the equilibrium are equal. Is that true? For example, in the case of HCl(aq), if we start with a solution of HCl 0.1 mol/L, the concentration of H+(aq) and Cl-(aq) after ionization will be 0.1 mol/L. But, what about acetic acid? If we start from a 0.1 mol/L solution, what would the concentration of H+ and CH3COO- be?

18.S3: Supervisor 1: Lower.

19.Coordinator: What will tell us how much of each species will arise in the solution? (The coordinator points to the board, specifically to H+ and CH3COO-). Which parameter will give us information on the extent of a reaction? (The coordinator writes the letter K the board).

20.S3: The equilibrium constant.

21.Supervisor 2: Oho! I'm learning what equilibrium is! To me, the masses were all the same during equilibrium,...

22.Coordinator: which is different from the concept that we have as common sense, in our day-to-day lives. If someone says that they are

> balanced, we think that good and bad things happen at the same proportion in their lives! [Laughter].
>
> 23.Supervisor 1: So I repeat: One has to choose the example and the situations they will use in the classroom very carefully so that they do not confuse the kids. This (chemical equilibrium) is one of the most difficult topics to teach.

In sciences, it is not possible for students to observe every thing that is studied. Thus, analogies have to be used to discuss the results. The application of models that provide adequate explanation will be valuable in this process. Several authors regard the study of chemical equilibrium as something abstract. Also, students experience great difficulty in understanding and assimilating such content (Johnstone, Macdonald and Webb, 1977). The biggest difficulties lie on understanding the coexistence of chemical reagents and products and the dynamic character of chemical equilibrium as well as on recognizing situations of chemical equilibrium and nonchemical equilibrium. One still has to imagine how the species behave according to the principle of Le Chatelier and to relate energy to the chemical phenomena involved in chemical equilibrium. In this sense, several analogies have been proposed to teach this concept (van Driel and Graber, 2002).

Bringing an everyday situation into the classroom and executing it well can aid students' understanding of unfamiliar concepts. Thus, analogies should be incorporated as a motivating tool to aid student learning (Harrison and Jong, 2005). However, it is worth noting that a faulty analogy can attribute misconceptions to the discipline.

According to Lewis (1933), several students lack preparation to teach a traditional sciences lesson:

> [...] They should use analogies because many students in introductory courses are not adequately prepared for a typical presentation of the theme, and, as chemistry is a growing science, the use of analogies is advisable until a more rigorous scientific presentation can be absorbed by the students. (p. 627)

In our analysis, we observed that the Undergraduate students started planning their lessons by trying to present a context they believed would convey chemical equilibrium. However, the contexts and examples they came up with ultimately demonstrated the understanding the Undergraduate students themselves had of the topic. The introductory speech revealed that the Undergraduate students perceived chemical equilibrium as something static, so they provided examples that bore certain analogy with common sense. Therefore, the example of a lake environment disrupted by a hydrochloric acid spill, a strong acid that does not lead to a situation of chemical equilibrium because it fully dissociates in aqueous solution, was a weak example. It is important that Undergraduate students master the concepts of the topic they will address in the High School classroom and re-elaborate them. In the specific case of chemical equilibrium, Undergraduate students must understand that the macroscopic characteristics, such as color and density, remain constant, and that the amount of both reactants and products cease to change after a certain time.

Another example based on analogy was given by S1: the tug-of-war scenario. In this case, the students suggested that the same amount of people should pull each end of the rope. This suggestion demonstrated that the Undergraduate students viewed equilibrium as a situation that entailed "equal forces, equal concentrations of reactants and products." The students used the tug-of-war example to suggest that the same amount of people at each end of the rope ensured application of the same force, but in opposite directions, which was also a misconception. Chemical equilibrium is not static, but dynamic. In other words, the reactions continue to occur, but they happen at equal rates and permanently, which ensures the equal rates of the opposite chemical reactions.

When S3 cited the treadmill model as an analogy to explain chemical equilibrium -"[sic] the treadmill runs to one side, and we move to the other side, without going anywhere"- such example was in line with Mickey's analogy (Mickey, 1980), whose reference to chemical equilibrium portrayed a person running over a belt. This illustrative aspect carries the idea of dynamism, where both the speed of the running person and the speed of the moving belt exhibit equal balance. Therefore, the treadmill model cited by S3 provided a clear view of reversibility. We also understood that the compartmentalized view of a non-closed system would not cause major interpretation issues. It would be possible to build an idea of the amount of concentration and to use the reaction involving reactants and products.

To teach chemical equilibrium, there is an abstraction that resembles the metaphor suggested by Hambly (1975), the analogy of the "Apples War" (Dickerson and Geis, 1981). This analogy depicts two neighbors throwing apples back and forth over the fence of their gardens. Launchers with different agility (representing the constant K) lead to different amounts of apples being accumulated in each garden (concentrations). Although both neighbors continue their castings, the number of apples on each side remains constant after some time. Once "balance" is achieved, the number of apples remains constant (Dickerson and Geis, 1981).

S3 cited the "equilibrium constant" as an answer, showing that they were using what they learned at University. Thus, the concentrations of all the substances present at equilibrium remain constant over time, which allows characterization of equilibrium by means of a number, the equilibrium constant (K), which indicates the ratio between the concentrations of reactants and products. When S3 mentioned "equilibrium constant" (K), it was noticeable that only memorization of the conceptual chemical structure occurred.

The teaching-learning process must provide elements for the construction of knowledge; this process must be dynamic rather than mechanical and rote. Contextualization should aid the teaching-learning process to rely upon practices that "seek to give meaning to school knowledge and use interdisciplinarity to avoid compartmentalization " (Ministério da Educação do Brazil, 1999, p. 12).

24.Coordinator: What about you, S7, how would you start your chemical equilibrium lesson?

25.S7: Well, initially, I would use something I've witnessed here in higher education. I thought I'd start the lesson with something like brainstorming.

S7 referred to their experience at University. S7 had developed a printed script and continued their speech by pointing out the items they had noted on an A4 sheet. S7 demonstrated thoughtful expressions and an apprehensive face. This was understandable because S7 was starting the Chemistry course at FFCLRP/USP.

26.S7: So, during this brainstorming, I would ask students what they understand, what they think, what they think about chemical equilibrium. And I would not everything they say, whether correct or not, on the chalkboard.

27.Coordinator: But is it equilibrium or chemical equilibrium?

28.S7: Chemical equilibrium.

29.Coordinator: Okay. Because they are different things, equilibrium, the knowledge they have based on their day-to-day experience, and chemical equilibrium. Would they already have any idea of what chemical equilibrium is? What do you think of that question, supervisor 2?

30.S7: And I thought of starting with that question, just thinking about it, because I wanted to use the students' answers to work with their ideas about the topic. I would compare what they said to what it is like in chemistry, and how it is studied in chemical equilibrium.

31.Supervisor 2: Actually, S7, I do not see any problem with you starting by asking students what they understand about chemical equilibrium. Most of them will tell you they do not understand a thing. From there, you could then start to change your question. You could even say, Okay, how about equilibrium? What do you understand about equilibrium? They would talk about a number of things. After that, you could ask, "Okay, and what chemistry has to do with it? What do we study in chemistry that can be related to equilibrium? They would also come up with some answers and then start making connections.

All the PIBID students took note of comments and discussion in the group. Attentively, the students wrote down the information provided by Supervisor 2 in their notebooks.

32.S7: Then, after students gave their ideas and I made adjustments according to their answers, I thought of sticking more to qualitative aspects, to conceptual definition, in that first class. Then, I thought of taking some graphs, rate versus time and concentration versus time, and

> using them to interpret chemical equilibrium concepts. And I thought of giving several examples and of working with each of the cases, so that students would see that there are conditions in which there are more products than reagents, more reagents than products, or equal quantities of reagents and products at equilibrium, which will all depend on the reaction.

S7 uses their notebook to show their colleagues the graphs S7 has brought to the meeting and which they plan to discuss with High School students in the classroom.

> 33.Supervisor 2: The example that S7 gave is one of the examples I use in my classes. But, S7, quite honestly, what you have written is enough content for two classes, at least. This brainstorming alone ...

In this case, S7 attempted to retrieve a day-to-day concept but realized that the concept was not as obvious as it seemed. S7 attempted to recall previous approaches used at college to introduce the topic. Still, S7 lacked sense of time (the supervisor warned S7 that their plan would take at least two lessons). With gestures, S7 and the other PIBID students demonstrated that they agreed with supervisor 2 that that specific idea for a lesson on chemical equilibrium would be more appropriately developed within a longer period.

In line with Vygotsky (1984, p. 12), "the word functions as the means to form a concept." Later, the word becomes the symbol of the concept. And only the investigation of the functional use of the word and its development from one stage to the next provides the key to the formation of concepts. "Every word evokes an entire complex system of links and becomes the center of all a complete semantic network" (Luria, 1986, p. 76). Moreover, Leontiev (1978) sees the importance of teaching taken as an activity, like the situation described here: the participation n of Undergraduate students in group meetings constituted a social process mediated by tools and signs; it was structured from a need (the need for the Undergraduate students to re-elaborate a lesson about chemical equilibrium) and required a particular organization.

> 34.S7: By the way, I was going to ask this; I had a hard time preparing this lesson. How many lessons can be dedicated to chemical equilibrium? This information would make it easier to get a feel.
>
> 35.Supervisor 2: As many as necessary. You cannot quantify the number of lessons, which varies from group to group.
>
> 36.S7: And that plan would be suitable for two classes, or around that.
>
> 37.Supervisor 2: Around that.

Interaction with the High School teachers helped the Undergraduate students to realize their difficulties in distributing content within the appropriate class time in High School. In addition, this interaction provided the Undergraduate students with the notion that approaching the class content in a simplistic way could lead High School students to misunderstand the topic. The

Undergraduate students learned that analogies must often be made with something that is familiar to the High School student and with something the students want to know. According to Harrison and de Jong (2005, p. 1136), "... analogies are simplified representations that may exaggerate the goal of emphasizing similarities between the analogy and the objective, so that scientific inquiry is stimulated."

> 38.S7: Thinking about it, here we have addressed, sort of, all the qualitative aspects, the main and the most general ones. And then, what about the quantitative aspects ...

> 39.Supervisor 1: You've got to think about it all quite well, because in practice...

After that, supervisor 1 reminded the Undergraduate students of the need to adjust both the depth and breadth of the content. The development of chemical concepts by students often depends on mediation of a more experienced teacher. The decoding of signs and the language used in class arise through this mediation (Nogueira, 1993). The supervising teacher holds the expertise regarding the scientific concepts to be taught. The following conversation proceeds according to this line of thought.

> 40.Supervisor 2: Yes. That depends on the pace of each class; the pace depends on how much students ask and on how much they want to know. Many times, a question goes completely off topic, but you cannot refrain from answering it.

> 41.Coordinator: And how would you do that, S10?

> 42.S10: By showing graphs. For example, a reaction.

> 43. Coordinator: Look at the graph!

> 44. S10: A concentration-time graph. The graph is horrible!

Concerning the question about how to deal with students' understanding of equilibrium as equality of masses, the undergratuate students replied that they would resort to the graphic method. Their speech referred to the importance of working from the image playback (Ferreira, 2010; Silva, 2006; Teruya, Marson, Ferreira and Arroio, 2013). Based on Bachelard, Lopes (2007) says that "images must be understood as reasoning models, not actual consequences" (p. 46). Man is up and reworks historical, social, and cultural interactions, such as those that permeate the thoughts and language of the school context (Vygotsky, 2001).

S10 presented a graph that misplaced time on the vertical axis and concentration on the horizontal axis. The other colleagues soon noticed the error and reported it.

> 45.S10: In the beginning, before the reaction happens, I have a particular concentration of the reagent here, and I have zero Product. From the moment the reaction starts to happen, the concentration of the reagent starts to decrease. Consequently, the mass of product rises until

it reaches a constant value, or equilibrium, and equilibrium will not necessarily occur when the concentrations are the same, or when the masses are equal. There may be cases when the masses are different, but there may be cases, for example (S10 draws a line where the product and the reagent masses are equal, demonstrating chemical equilibrium), when they are equal. Therefore, when balance is reached, masses will not necessarily be the same.

46.Coordinator: Teacher, if there is no equilibrium, what is the graph like?

47.S10: If chemical equilibrium does not exist, there will not be a constant line (S10 deletes the line that shows chemical equilibrium, and represents the plot for a reaction with no chemical equilibrium).

48.Coordinator: But then? What about the reaction rate? We see equilibrium there!

49.S5: But speed has to do with time!

50.S10: Exactly! When I increase time, the concentration will vary, and the speed at which the concentration changes varies with time.

51.S7: Then, we could work with another graph of reaction rate versus time to show that in every situation of equilibrium, regardless if there is more product than reactant at equilibrium or vice versa, the rate of the forward reaction will always equal the rate of the reverse reaction.

52.Coordinator: But teacher, I still do not understand. If you do not have equilibrium, what does the graph look like? Get us another graph! Let's see how the graph looks without that equilibrium stuff.

S10 proved to be totally lost in their approach, indirectly signaled not knowing how to answer the coordinator's question, and eventually sat down. S5 then rose and headed toward the chalkboard to draw the graph.

53.S5: Well...

54.Coordinator: Go for it!

55.S5: So, here we go. If a reaction does not reach equilibrium, what happens? This reagent continues being consumed until there is no more reagent, and this product continues being formed, so that no equilibrium occurs.

56.Coordinator: S10, did you get why your graph was wrong? The rest of you, did you get it? Later on, Supervisor 2 will comment on this.

57.Supervisor 1: Go back to that part again. What runs out?

58.Coordinator: It's different!

The development of lesson planning revealed both Undergraduate student growth and evolution of the speech and language they used to discuss the target topic. For example, the Undergraduate students admitted that the example of tug-of-war was not satisfactory because it provided an idea that constrasted with the dynamic nature of chemical equilibrium. They suggested brainstorming and working with concepts through graphs. They presented the graphs and discussed their potentials and limitations. Student growth also occurred when the Undergraduate students replied to the coordinator's questions concerning information on the extent of a reaction (H^+ and CH_3COO^-). The whole process forced the Undergraduate students to resume the theoretical knowledge they acquired at University and to re-elaborate the concept of "Equilibrium Constant" by making an analogy between the concept and their response.

In the process described herein, the first proposal a student made was to show an example of environmental contamination; more specifically, hydrochloric acid spill in a lake and its impact on the natural balance of the ecosystem. Context in education is an important and outstanding condition of all learning materials and legal education documents, and undergratuate students know that. In this sense, efforts to seek correlations with daily life are always made because Undergraduate students are still in the process of formation. These correlations often lead to misconceptions, which probably happen because Undergraduate students do not apply the concepts they learn at University to practical situations. University teachers do not always stimulate Undergraduate students to consider the complexity of natural phenomena. For reasons that often include the curriculum, higher-level courses emphasize fragmented learning. Undergraduate students are still taught with little articulation, and they learn concepts that are restricted to very specific processes within the large field of chemistry. Therefore, when undergratuate students see themselves in a classroom with a group of younger students, with much less class time as compared to lessons at University, without many teaching resources, without the possibility of teaching practical classes in the laboratory, with heterogeneous learning conditions, and with the need to teach the "same" content they learned at University, these students will face difficulties that may jeopardize teaching and learning.

Conclusion

In the process of conceptual re-elaboration, Undergraduate students resort to analogies without questioning their limitations. Such attempts to simplify concepts employing examples from everyday life often end up with misconceptions.

Contextual teaching is not a routine at university, but it is a routine in high school. Thus, the challenge that university mentors have to face when undergraduate students do their initial training for teachers of Chemistry is to prepare these students to teach the contents they learned in a compartmentalized fashion in an articulate way, through an interdisciplinary approach. The contrasting scenario between university and high school education has resulted in superficial education and serious trouble.

After proposing contexts to teach chemical equilibrium, the Undergraduate students suggested analogies with the treadmill, the tug-of-war, and the Apple war. However, after being questioned in more specific terms, the students realized they could not maintain an explanation by using analogy alone. They came to the conclusion that it is necessary to understand how chemical species interact, if they dissociate and ionize, if response is fast, not to mention that molecular weights and acid strength must also be considered. Finally, the graphic element helped to condense knowledge of a complex chemical process.

The undergraduate students spent more time worrying about lesson content than considering class time and accounting for the fact that planning must focus on the actions of the individual in their role as teachers. Admittedly, the Undergraduate students were sensitive to which chemistry content require connection with didactics, and they resorted to different dynamics, including lectures, discussions, exercises, and the use of graphs. When they had to plan and discuss topics in groups, the Undergraduate students realized their mastery of the topic and concluded that exchanging ideas could help them to strengthen their knowledge. To sum up, the language the Undergraduate students used, in the context and theoretical sense of Vygotsky, clearly changed over the development of the planning sessions.

Implications

The conception that being a teacher of Chemistry essentially consists of mastering specific syllabuses and pedagogical techniques is rather limited. Given that teaching practice is both complex and contextualized and includes concurrent practices, the lesson taught in the classroom can only be understood or examined from the perspective of the influences it receives from other practices. Examples of such practices include the school board, state policies, and reference guides of teaching materials.

The PIBID internship is distinctive due to the planned and collaborative nature it fosters among active academic staff and undergraduate students of Chemistry. Planning begins by objective grasp of school conditions and interaction with high sSchool teachers.

According to Vygotsky, all phenomena can be understood within their changing process. The control of human nature and behavior control are interrelated; the change individuals cause in their inner nature alters human nature per se.

To Vygotsky, the teaching-learning relationships in an educational process are based on understanding of the development of human psyche. Thus, studies on the Theory of Activity in the context of human development are crucial. According to Leontiev, humans learn when they are active. This theory emerged in the field of psychology, from the works of Vygotsky and Leontiev. The Theory of Activity represents an unfolding effort to build a socio-historical-cultural psychology grounded on Marxist philosophy.

According to contemporary reflections, the investigation of concepts allows diverse conceptions regarding the nature of chemical equilibrium to be identified. The conceptual world is constantly reorganized through association between words. The relationship between thought and speech changes during development, as observed during the PIBID group meetings. Therefore, concepts and cognitions are organized into a network of meanings comprising relationships among the elements and not as isolated entities in the subject's mind. Consequently, both the elements word and concept undergo constant change within the subject's psychological structure. These elements relate to each other dynamically, producing the human psyche.

When planning of an educational activity is concerned, formation of undergratuate students is put in motion, and knowledge about the chemical content surfaces, allowing identification of weaknesses. Group discussion allows everyone to revise their knowledge and rework it.

The excerpts presented here showed different moments of a meeting in which the focus was the teaching of chemical equilibrium content. The dynamics of speech and social interaction revealed that the process of knowledge appropriation depends not only on linguistic agreement, but also on semantics, imagery, and perceptual convergence. During the time they studied and proposed pedagogical actions, the participants discussed teaching methodology and the content itself. Emergence of doubt and "no knowledge" fostered the learning process and highlighted the fragility and incompleteness of Initial Training of teachers of Chemistry at the same time that it pointed to the need for continuing education of current teachers of chemistry.

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