In figure 5, results are reported related to the two questions: A) the materials used, in your opinion, have proved to be a) suitable for the purposes and of easy use at school, b) suitable for the purposes but not easy to use at school, c) not suitable for the purposes; B) in your opinion the teaching approach has been a) successful, b) quite successful or c) not successful. The teaching approach was consistently considered successful and interesting, as it was for the materials and equipments used in the laboratory activities. Different opinions were gathered about the possibility to repeat, continue or implement the attended experiments at school. On this point, different answers are probably due to the different complexity of the activities proposed depending on the school level. Thus, Primary school: more than 75% of the teachers thought that the lab activity could be repeated at school. Lower secondary school: practically all of the teachers found the experiments (and related materials) suitable to be proposed again at school by themselves. High school: here the opinions overturn, the teachers found the lab activities not easy to reproduce at school on their own forces.

CONCLUSIONS

The communicative approach used during visits to the museum, based on the engagement of the visitors in the construction of an interactive contest, has proved very satisfactory, particularly for young audiences. This is probably due to their natural curiosity and to their power of observation thanks to an age at which the acquisition of new knowledge is done with enthusiasm and active participation. On the other hand, it proves to be somehow more difficult to raise interest and curiosity about scientific historical exhibitions when the audience consists of high-school students, who usually better appreciate practical laboratory activities. That is why, altogether, a degree of satisfaction even higher has occurred in the evaluation of laboratory activities.

Nevertheless, it remains an important goal, the possibility for students of attending some experimental activities they usually do not have the opportunity to do at school, though in the context of the so-called informal science education (Orlik, 2003).

In summary, we can say that the strengths of this project, which will be further improved in the future, are essentially the following:

-*Adapting to a young audience the exhibition routes*, making them more attractive and interactive.

-*Making easily accessible the interesting collections* in the Museum, conveying concepts of high scientific and historical value to a wide audience.

-*Linking each selected museal tour to specific activities* to be carried out in a real scientific laboratory.

-*Increasing the development of multimedia resources*, such as online renew database, virtual interactive visits to the museum.

- Developing an application that allows to play online with the "museum memory game" with which students can enjoy in the recognition of objects and tools seen at the museum, associating the photo of the instrument to its name and to its description.

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Learning in a community of practice: the case of pre-service chemistry teachers

El aprendizaje en una comunidad de práctica: el caso de los profesores de química en formación

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Abstract

What makes the teaching of chemistry a challenge for teachers. In this paper, we have explored communities of practice (CoP) as a viable alternative for teacher training of chemistry. The power of CoPs is through the interactions within the group, and the opportunity to share experiences, so that teachers can learn about new trends in chemistry education and practice in class. This work shows the contributions of a CoPs designed in the project PIBID of the University of São Paulo for the learning of pre-service chemistry teachers. The results show that, in the CoP, the pre-service chemistry teachers have learned about the teaching practice and working effectively in groups; the connection of the practice of teaching; and group engagement on sharing experiences as main factors that favored learning.

Key words: *community of practice, teaching knowledge, pre-service teachers training.*

Resumen

La química es una asignatura difícil de aprender, lo que hace que la enseñanza de la química un reto para los profesores. En este contexto, las comunidades de práctica podría ser un buen ambiente para la formación de profesores. Intercambiando la experiencia en las comunidades de práctica, los profesores pueden aprender acerca de las nuevas tendencias en la enseñanza de la química y practicar clase. Este trabajo muestra las contribuciones de una comunidad de práctica diseñada en el PIBID, proyecto de la Universidad de São Paulo para el aprendizaje de los profesores de química en formación. Los resultados muestran que, en la comunidad de práctica, los estudiantes de licenciatura de química aprenden sobre la práctica docente y el trabajo en grupo, la conexión con la práctica de la enseñanza. El intercambio de experiencias fue el principal factor que favoreció su aprendizaje.

Palabras clave*: comunidad de práctica, enseñanza de química , formación de profesores en formación.*

INTRODUCTION

Chemistry is an important part of science; because it enables learners to understand the world around them. The learning of chemical concepts and explanations of chemical phenomena rely on understanding the microscopic world that is connected with the phenomenological world, both of which are communicated with symbols (Jhonstone, 1991). Thus, the conceptual understanding in chemistry includes the ability to represent and translate chemical problems using macroscopic (observable), molecular (particulate), and symbolic forms of representation (Gabel & Bunce, 1994). The abstract concepts and the difficulty in translate these concepts for macroscopic and symbolic representations is what makes chemistry a difficult subject for many students.

According to Johnstone (2000), integrating these forms of representations is an important process needed for a comprehensive understanding of chemistry. Although this ability is an essential tool in the full appreciation of natural phenomena, the acquisition of this ability remains a significant challenge for the teaching of chemistry.

Sirhan (2007) shares the areas of difficulties in chemistry, which include: selection of the curriculum content; cognitive overload of students' working memory; language and communication; and motivation. According to the author, the key lies in visualizing chemistry from the point of view of the student learner. Is vital for teachers to know what learners already know, how they gains knowledge and what motivates them.

Teachers are constantly having difficulties helping students understand the abstract concepts of chemistry and asking them to translate the macroscopic observations from microscopic phenomenon. Moreover, teachers need to be in constant attention to know students' difficulties and what motivates them to learn.

Communities of practice (CoP) have been shown to be effective learning environments. Communities of practice is described by Wenger, McDermott and Snyder (2002) as a group of people who share a concern, a set of problems, or a passion about a topic, and deepen their knowledge in this area by interacting among them, developing personal relationships and practicing. According to Wenger (2008) the participation in a CoP results in the process of learning, by the process of doing practice, belonging communities, experience meanings and becoming a member.

In teacher training, prior research has showed that the involvement of teachers in CoP leads to positive outcomes, since they provide support for teachers to implement their instruction, professional growth and the opportunity to practice their knowledge and share experiences with other members (Akerson et al., 2012; McDonald et al., 2008; Santos & Arroio, 2013).

Wenger (2008) defines learning in a CoP as result of the community members' engagement, the sharing of ideas and the work towards a joint enterprise. According to the author, in a professional group the learning could be related to the training of individuals for their profession. Thus, in a CoP, chemistry teachers can learn about the teaching of chemistry for a better appreciation of their students.

An example of a CoP is the Project PIBID (Programa Institucional de Bolsas de Iniciação à Docência – Institutional Program of Grants to Initiation to Teach) developed at the University of São Paulo, Brazil. The PIBID is a Brazilian program that offer grants for undergraduate students to participate of projects in several areas of teaching. These students have the opportunity to experience teaching practice, being inserted in public schools to develop activities of teaching.

The project PIBID of chemistry aims to promote training for pre-service chemistry teachers, preparing them to build teaching methodologies using visual tools for teach chemistry and promote students' understanding of chemistry in the microscopic and macroscopic levels, making links between them.

In a previous work (Santos & Arroio, 2013), the group of pre-service chemistry teachers, participating of the PIBID project, was characterized as a CoP, since it presented three dimensions proposed by Wenger (2008) that characterizes a CoP: mutual engagement, joint enterprise, and a shared repertoire.

This work aims to show the contributions of the CoP designed in the project PIBID for the learning of participating pre-service chemistry teachers.

METHODOLOGY

The project PIBID of chemistry carried its activities aiming to improve the training of teachers to teach chemistry using visual tools. In a partnership with a public school, the project included 14 pre-service chemistry teachers of different years in the chemistry undergraduate program.

The activities of the project included weekly meeting where the pre-service teachers were provided theoretical training on topics related to visualization, chemistry teaching and teacher's practice. Coupled with these trainings, the pre-service teachers produced, in groups, didactic sequences supported by visual tools and applied these sequences to high school students. The group of pre-service teachers were divided in seven groups of two people each, called work groups. In these groups, pre-service teachers planed the sequences of activities and applied them at the school. Chemistry and science teachers from the public school supervised the groups.

For this research, the group was accompanied during their discussions and preparation of didactic sequences at the weekly meetings. Notes were taken and the discussions were recorded with an audio recorder. At the end of the year, a questionnaire was applied with questions about what they have learned through the project, as showed in Table 1.

Table 1. Questionnaire applied to the pre-service teachers

What have you learned during the project?	In what situations?	Who helped you in this learning?

Interviews were also performed with questions about the development of the group and of the individual. These interviews helped to understand the pre-service teachers learning during their participation in the project. From the data obtained at the questionnaires and interviews, categories of responses and possible explanations were identified.

The work was analyzed for what the pre-service teachers have learned at the activities in the PIBID and how this CoP have assisted their learning about the teaching profession. Of the 14 pre-service teachers participants, only ten answered the questionnaire, and all participated in the interviews. The research was completed with the permission of the pre-service teachers.

RESULTS AND DISCUSSION

The answers obtained at the questionnaire were divided in categories and the percentage of answers obtained in each category is displayed in Table 2. Many answers were placed in more than one category. Each category will be discussed separately.

What have you learned during the project?

The pre-service chemistry teachers' responses are summarized in two main categories: learning for the teaching practice and learning for the work in group. The results show that a significant portion of the students' learning was related to the teaching practice, that is, issues related to how to prepare class plans and reports, as well as, the methodology and didactic for teaching chemistry. Most pre-service teachers reported that they learned how to plan classes, in order to have autonomy to modify the activities planned according to the students' necessities, avoid lectures and increase dialogue with students. On questionnaires and interviews, the pre-service teachers reported:

> *"I've learned how to plan a class, analyze the results and discuss changes. I also have learned how to appropriating-me of information from scientific papers for improve my class plan".*

Table 2. Percentage of answers obtained in the questionnaire

What have you learned during the project?		In what situations?		Who helped you in this learning?	
Learning for the teaching practice	Learning to work in groups	During the meeting with the group	During the classes at the public school	The group of participants of the program	Students from the school
90	10	63	58	96	23

> *"Learning how to teach avoiding lectures was good to improve the students' learning and I think that it could help me in the future, when I become a teacher".*

Many pre-service teachers have also reported that they have learned how to deal with some situations in class, as well as, lack of discipline, teaching a heterogeneous group, and modify languages and examples for everyone to understand.

> *"One important thing that I have learned was how to conduct a class (...). I learned to plan me for unforeseen, to think in the next step, think in alternative ways of explanations (...)".*

A large part of the pre-service teachers stated that they have learned about different tools to improve the teaching and learning of chemistry. They have essentially learned about the use of visual tool in the teaching of chemistry, as models, experiences, movies and pictures. They have also learned how to teach chemistry in a multimodal way, involving interaction of visual and linguistic tools, aiming to improve learning of chemistry, as stated by some science education researchers (Jewitt et al., 2001; Lemke, 2006).

> *"I always thought that chemistry must have this visual tools (...) and I thought it was cool the project propose this. The experiments we made, the models with adapted materials, as Lego and play dough, made the difference on the students' learning".*

About the work in groups, the pre-service teachers stated that at first, many of them faced difficulties in the work in pairs, mainly because of the differences between pre-service teachers. At the end of the year, some pre-service teachers stated that they have learned to work in groups, to discuss and listen to others aiming to create a good job.

> *"I've learned to respect other people's opinion, but also show my opinion according to correct arguments".*

> *"With the discussions at the meetings, I learned to listen to criticism and use them in constructive way".*

In what situations?

The main answers provided by the pre-service teachers to this question are related to learning in the group's meetings or at the classes, teaching chemistry. Most of them gave both answers, showing that the learnings at that community of practice were guided by the involvement in the group, listening to the other's opinion, and the involvement in the practice of teaching. However, when questioned about this answers at the interviews, the pre-service teachers showed that although the group discussions were constructive, the learning obtained at these moments were simply consolidated in the practical work, as stated by one pre-service teacher:

> *"When people told me, in the meetings, that our class plan looked as a lecture, that we should change it, for me it had no effect, I thought that in the class I could change. However, when I gave the class, I saw that it was not good for the students. So then, I have learned that I have to change".*

> *"A set of factors helped me to learn about teaching chemistry. The discussions about the papers, the theories, the action of thinking about what to do, the group's help in my classes planning..."*

Who helped you in this learning?

In this question, most pre-service teachers answered that the group of participants in the project was the primarily responsible for their learning. Some of them stated that the students from the public school also helped them in their learnings.

The group's influence on learning occurred not only during the meetings, but was also perceived during the classes at school, since the group helped the pre-service teachers in their chemistry classes at school. The learning with the group occurred in a directly way, with advices during the meetings, and in an indirectly way, observing other groups in their classes.

> *"My partner helped me a lot in my learning. And in the classes, observing the other pre-service teachers in their classes".*

The results presented here show that the involvement in a community of practice helps pre-service teachers learn about the teacher practice. By the pre-service teachers' statements is possible to see that the work in group, the possibility to share experiences, discuss ideas and practice what they have learned were essential to their learning.

Despite the learning is not the embodied goal of the pre-service teachers when participating of the project (many of them related that their aim was the experience of teaching), their experience led to learning. In this sense, the pre-service teachers learning is not static, but a process of being engaged, participating in a CoP.

To not trivialize the concept of learning by saying that everything people do is learning, Wenger (2008) stated that a significant learning in CoP includes three process: evolving forms of mutual engagement; understanding and tuning their enterprise; developing their repertoire, styles; and discourses. Thus, learning in CoPs is related to the development of a mutual relationship, aligning the engagement with the community enterprise and negotiating the meaning of various elements.

By examining the results, it is possible to conclude that the pre-service teachers have learned many things related to the teaching of chemistry and their work in groups. The outcomes were developed by the mutual relationship with the other pre-service teachers and by the engagement in the practice of teaching. In many moments it was possible to observe that the pre-service teachers were concerned to the group enterprise of teaching chemistry using different visual tolls to promote a dialogued class. This concern led them to learn about minimizing lectures and the use of visual tools to teach chemistry. Ultimately, the pre-service teachers have stated that the other pre-service teachers helped them in their learning, by sharing of repertoire and discourses, and negotiating meaning.

Thus, learning is connected with the practice, in the sense that it sets the learning, but learning is also connected to the group engagement, the support of other community member. According to Wenger (2008), CoPs should not be reduced to purely instrumental purposes. They are about knowing, but also about being together, living meaningfully and developing a satisfying identity.

CONCLUSIONS

This work showed the learning of pre-service teachers by the involvement in a CoP. A significant aspect of the students' learning was related to the teaching practice, that is, issues related how to prepare class plans and reports, as well as, the methodology and didactic for teaching chemistry. The students reported that beyond the learning in practice, in the relationship with students, they also have learned substantial concepts at the meetings, interacting with other pre-service chemistry teachers. The results show that the CoP contributed for the learning of pre-service chemistry teachers since their learning was connected with the practice and with the group engagement.

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