Are science teachers prepared to promote argumentation? A case study with pre-service teachers in Bogotá city

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Contents

Abstract

This paper addresses the importance of argumentation in science education. A research project was done in order to know how a group of pre-service chemistry teachers has been prepared to promote students' argumentation. A Chemistry degree studies plan from a Colombian university was surveyed, and 18 future teachers' representations about argumentation were analyzed. Results indicate argumentation is not an explicit priority for the pre-service chemistry teachers training program studied. Additionally, future teachers showed consciousness about the necessity of being prepared to engage students successfully in argumentative activities. Nonetheless, pre-service chemistry teachers manifest not to know how to design multiple methodologies to improve argumentation. Therefore, one of the multiple proposals of solution could be the incorporation of a module that allows pre-service chemistry teachers to build their own strategies to promote argumentation.

Keywords: argumentation, chemistry education, pre-service science teacher training, science education.

Introduction

Cademartori and Parra (2004) and Xie and So (2012) recognize that if the school encourages falsifying scientific knowledge using argumentation, this will offer students the possibility of rectifying their own ideas and of promoting the creation of a more critical learning environment. Supporting this idea Archila (2012, 2014ab), Erduran et al. (2006) and Stipcich et al. (2006) mention the necessity of including argumentation in science teacher training programs so as to give the opportunity of future teachers to build their own tools that permit them to promote argumentative skills with students.

Recently, argumentation was included by the first time in the "Second International Handbook of Science Education" edited by Fraser et al. (2012), in a unique section entitled "Argumentation and Nature of Science" which consists of eight chapters in which foundations, progress and challenges of argumentation and science education are discussed. This handbook shows the importance of studying how to

use argumentation successfully to help learners construct knowledge socially. On top of that, the role of science teachers is crucial when they design and apply innovative teaching strategies that engage students in the promotion of their argumentative skills (McDonald & McRobbie, 2012; Milne, 2012; Geelan, 2012; Jiménez-Aleixandre & Puig, 2012; Osborne, 2012).

The inclusion of the study of argumentative practices in pre-service science teacher training programs is important to facilitate the creation of science education processes, in which students are invited to understand and use rules of reasoning commonly employed in scientific work, taking them to investigate the reasons, discuss the feasibility of data, and evaluate alternative hypotheses. This process allows them to discover that the natural sciences are more than trying to build and solve problems under specific theoretical models (Muller & Perret-Clermont, 2009).

This article attempts to answer the question "Are science teachers prepared to promote argumentation?" Data comes from a research project developed with 18 pre-service chemistry teachers from a university in Bogotá, Colombia. The training program was underwent a revision to determine the types of possibilities offered to future chemistry teachers so as to help them to promote argumentation. The results of this research demonstrated the necessity of preparing future chemistry teachers to teach students how to learn through argumentation.

Literature Review

The challenge of pre-service science teachers training programs

Woolnough (2000) affirms that pre-service training programs for science teachers have a significant influence on future teachers' perceptions of science and teaching. This author demonstrates the necessity of doing drastic changes in contents and methodologies that have been arranged for the preparation of future science teachers. Orienting pre-service science teachers to build criteria must be a priority because it would enable them to decide on changes, such as the incorporation of argumentation in their training. Thus, Pérez (1992) suggests that teachers should learn in basic training and not only acquiring and reinterpreting the culture developed in the academic disciplines.

Added to that, Kagan (1992), after studies about the professional development of novice teachers, found that teaching in the first year of work seems be a period during which the teachers learns to know their students, use their knowledge to modify and reconstruct their conceptions and develop a standard procedural routine that integrates class practice and instruction. Based on the idea that pre-service training is the only source of substantiation that teachers have to do their work, some professional development courses have been created. Nevertheless, the results are not the best because those teachers repeat their classes as usual and little innovation was found (Archila, 2010). Briscoe (1991) mentions that this trend is due to the absence of a theoretical body of knowledge in science education, fully constructed and recognized by the teachers who, at the same time, should appropriate their profession during their pre-service training process.

Research done about promotion of argumentation in training programs

Archila (2012) distinguishes two distinct categories of research and development with respect to the study of argumentation from a linguistic vision and its contributions to science education. This author suggests that those categories should be taken into account to prepare future chemistry teachers. The first category is related to theoretical foundations demonstrated in the studies of Andriessen and Schwartz (2009), Baker (2009), Bisault (2008), Duschl (2007) , Erduran (2007), Erduran and Jiménez-Aleixandre (2007), Garcia-Mila and Andersen (2007), Jiménez-Aleixandre (2007), Kelly et al. (2007), Kolstø and Ratcliffe (2007), Muller et al. (2009), Rigotti and Greco (2009), Sandoval and Millwood (2007) and Schwarz (2009). The second category concerns the study of argumentative practices in science education supported on the research projects of Andriessen (2009), Archila (2013a), Buty and Plantin (2008a), Clark et al. (2007), El-Hani and Mortimer (2007), Fillon and Peterfalvi (2008), Greco (2009), Henao and Stipcich (2008), Héraud et al. (2008), Jiménez- Aleixandre and Díaz (2008), Mercer (2009), Muller (2008), Orange et al. (2008), Rebière et al. (2008), Simonneaux (2007), Simonneaux and Albe (2008), Stipcich et al. (2006), Texeira (2010), Zeidler and Sadler (2007) and Zohar (2007).

In the last two decades, less than 30% (see Figure 1) of research has been devoted to preparing future science teachers in how to promote argumentation in the learners (Archila, 2012). The categories theoretical foundations and argumentative practices in science education confirm that argumentation plays an important role in the manners that students build understandings and conceptions of school

science knowledge, in which there are diversity of responses to argumentative questions that cannot be saturated by a yes / no answer, or by a contribution of information (Plantin, 2010). Incidentally, argumentation in the field of science education has been established as a multidisciplinary issue addressed in its remarkable depth for language sciences (Buty & Plantin, 2008b). This last point explains why it is necessary not only to prepare future chemistry teachers to design effective strategies that promote argumentation, but also offers them serious theoretical foundations of argumentation including history and perspectives.

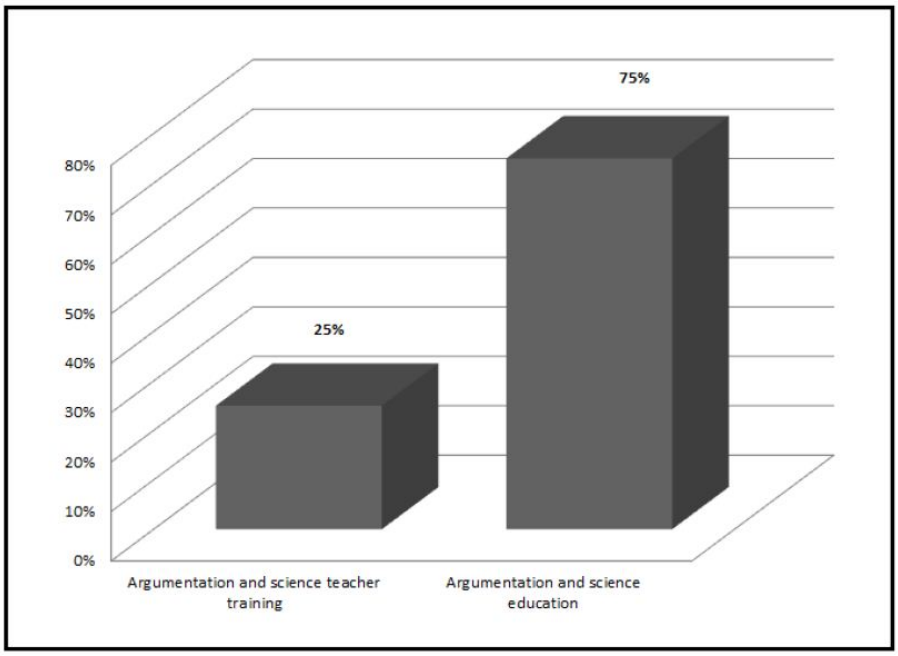

Figure 1. Research on argumentation 1990-2010 (Archila, 2012:368)

Zohar (2007) analyzes the teaching of science and professional development through argumentation. This author poses the following questions: what do future teachers need to know to incorporate argumentation to their class activities? And which characteristics should pre-service science teacher training programs have to promote the building of that knowledge?

Furthermore, Archila (2014b) confirms the necessity of preparing future chemistry teachers to take advantage of argumentation (and others thinking abilities) to enhance learning. Some of the subjects pre-service chemistry teachers take should be profitable academic places to build strategies to help along students' argumentation (e.g., history of chemistry, organic chemistry, epistemology of chemistry, biology, statistics, physics), (Archila, 2014a, 2013b).

The theoretical framework that has been addressed through this section is used to explore some approaches of argumentation; incorporation of this thinking ability requires a particular view of teaching and learning. In other words, it is not only acquiring information or appropriating objects of knowledge already developed, but also the emergence of new understandings and creative restructuration of prior knowledge. Students are coauthors of constructive socio-cognitive process in which argumentation offers diverse potentialities; those should be identified in pre-service science teachers training programs (Muller & Perret-Clermont, 2009).

Methodology

The Methodology is divided into two phases. Firstly, one program offered to future chemistry teachers was surveyed to determine if argumentation was included implicitly or explicitly. Secondly, a questionnaire was applied to 18 pre-service chemistry teachers from ninth semester. This instrument permitted knowing some representations and practices about the place of argumentation in the preparation of 18 individuals.

Data collection

In the first phase the Administrative department, responsible of the chemistry degree, provided useful documents related to the studies program implemented to prepare future chemistry teachers. The names of 70 mandatory subjects were revised and the syllabus of one subject was studied to determine if pre-service chemistry teachers had the opportunity to be prepared in how to promote argumentation in high school students.

In the second phase the questionnaire was validated by experts from the Universidad Distrital Francisco José de Caldas (Colombia) and the Université Lumière Lyon 2 (France). Firstly, the questionnaire was applied to six pre-service chemistry teachers of ninth semester. This first application allowed improvements and consolidation to the instrument. Secondly, the final questionnaire (20 questions) was administrated to 18 pre-service chemistry teachers ninth semester. To answer the questions, 18 individuals arranged time they deemed necessary in order to promote the reflective nature of the questionnaire.

The elaboration of the questionnaire responds to categories that allow knowing some of the representations and expectations of future chemistry teachers about the

place of argumentation in the studies program offered by their university and their role in promoting high scholars' argumentation. To structure the instrument, representations are understood as "... forms of practical thinking, oriented communication, understanding, and management of social, material and ideal environment" (Jodelet, 1986:474). For the purposes of this article, eight questions selected (9, 11, 14, 15, 16, 17, 18 and 19) were analyzed.

Data analysis

Firstly, 70 subjects that conform the chemistry degree's studies program were classified in three groups: disciplinary, pedagogy and didactics, and others. This classification permitted to choose one subject from pedagogy and didactics; known as "Professional practice teaching II". This subject was chosen because it permitted to have information about the 18 pre-service chemistry teachers' practices. Secondly, syllabus of the subject chosen was examined: objectives (of teaching and of learning), theoretical foundations (problematic and thematic nucleus), classroom practices proposed, competences to be developed, and assessment strategy predicted.

18 pre-service chemistry teachers from ninth semester volunteered. Data collected after application of the questionnaire were treated separately question by question using Microsoft® Excel. This program was used during phases one and two because of its usefulness in managing the lists and/or databases, which can sort and filter information (Charte, 2010).

Findings

Related to the program for future chemistry teachers

After classifying the 70 course work of the chemistry program, this research determined three groups: **discipline** (general chemistry, inorganic chemistry, organic chemistry, chemical analysis, radiochemistry, biochemistry, biology, physics, statistics, calculus, etc.), **pedagogy and didactics** (pedagogy, didactics, sociology of education, history of chemistry, methodology of research, education policy, bioethics, psychological paradigms, culture and education, etc.) **and others** (use of second language, theories of media and communication, elective courses, etc.). Discipline, pedagogy and didactics have proportional distribution in the studies program (see Figure 2), 38,57%; 34,28% striking a balance between

contents and strategies in chemistry teaching processes. Nevertheless, no subject related explicitly to argumentation was found. Although argumentation must be present in teaching and learning of all subjects studied by future chemistry teachers, it is imperative to include a course dedicated to the promotion of argumentation in learners.

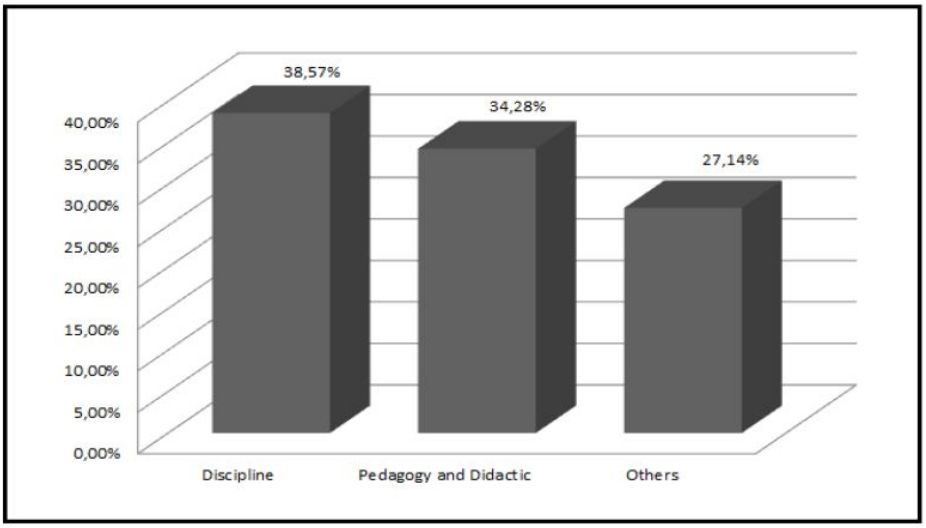

Figure 2. Percentage of group of subjects in the studies program

Argumentation is not assumed explicitly as part of the course work. To know if there is an implicit assumption, one course from the group pedagogy and didactics was chosen due to its clear possibilities to promote argumentation in pre-service teachers. Results of syllabus review (document provided by administrative department of the university studied) are shown on Table 1.

Table 1. Place of argumentation in a course oriented to future chemistry teachers

Group	Pedagogy and didactics		
Subject	Professional practice of teaching II		
Semester	9th of 10		
Purpose	"Professional practice of teaching is the approach to the school reality as an object of knowledge that enables the joint between the theoretical and practical aspects alluding to the dimensions determined by the school context, disciplinary domain, historical and epistemological teaching chemistry and assessment processes".		
Is argumentation	**Explicitly**	**Implicitly**	**None**

mentioned in these components?			
Mission			✓
Vision			✓
Problematic nucleus			✓
Thematic nucleus			✓
School practices proposed	✓		
General competences to be developed	✓		
Professional competences to be developed			✓
Objectives of teaching		✓	
Objectives of learning			✓
Teaching strategies		✓	
Assessment	✓		

The purpose of the subject “Professional practice teaching II” (see Table 1), demonstrates the possible impact it must have so as to allow future teachers to analyze, during the teaching practicum (with high school students), provided during this subject some strategies to teach students how to learn chemistry through argumentation. Nonetheless, results of a rigorous review of the syllabus (see Table 1) reveal that argumentation is not a priority in this course. This thinking ability is mentioned explicitly only in 3 of the 12 categories studied. Besides in those three times, argumentation is understood as an ability to be developed by the pre-service teachers (that is important) but tools future teachers will need to generate good practices of argumentation (that is the key) with high school students are not treated.

The first finding responds to the question: Are pre-service teachers prepared to address questions to students accepting and discussing alternative answers?

The questionnaire solved by 18 future teachers indicates that all pre-service chemistry teachers consider it is important to address questions to learners

accepting and discussing alternative answers and diverse points of view. It is a good beginning because this action would promote free discussions between students and increases possibilities of interactions necessary to argumentative practices (Plantin, 2009). However, it is not clear if they know how to do it. These are some comments future teachers made:

> "To understand [the student] that there are no simple answers and can generate different approaches based on different theoretical frameworks".
>
> "In the discussion of each student's argument is evaluated, is the only way I would think to assess the knowledge, not enough to give right or wrong answers but as advocates and described".
>
> "When you ask a question to a student is to seek the best way to answer it based on what you know and knowing to generate this raises several questions in the student a question with which it is sought more ways to answer those questions".

Comments indicate that posing questions to students would have apparently two defined goals. The first one has to do with the opportunity that students show respect for the opinions of others and recognition of the existence of divergent opinions. And the second one is closely related to the dialogical argumentation in which students interact with pre-service chemistry teachers while would know and defend their ideas.

The questionnaire also demanded future teachers to provide two examples about possible strategies so as to formulate questions to students accepting and discussing various answers. Results confirm the mayor difficulties future chemistry teachers have to use pedagogical and didactic tools that enable them to promote argumentative abilities (among others) in students. These tools should be built in the preparation process lead by education faculties.

The second finding responds to the question: Are future teachers prepared to manage spontaneous interventions of students in chemistry class?

On the one hand, 100 % of individuals agreed to accept the spontaneous interventions of the students. The comments evidence that most trainees manifest clarity about the contributions of spontaneous interventions offer to educational process. Nevertheless, there are some comments suggesting those type of

interventions could mean an obstacle to the development of chemistry class. A pre-service chemistry teacher affirms spontaneous intervention would be useful only if "favors progress of the class or having to do with issues the same and not disruptive". Hence, it is important to prepare future chemistry teachers about how to guide those types of interventions that could enrich class discussions generating student learning. On the other hand, Figure 3 shows that 83.33% of future chemistry teachers manifest none opportunity (during their studies) to be prepared about how to manage spontaneous students' questions.

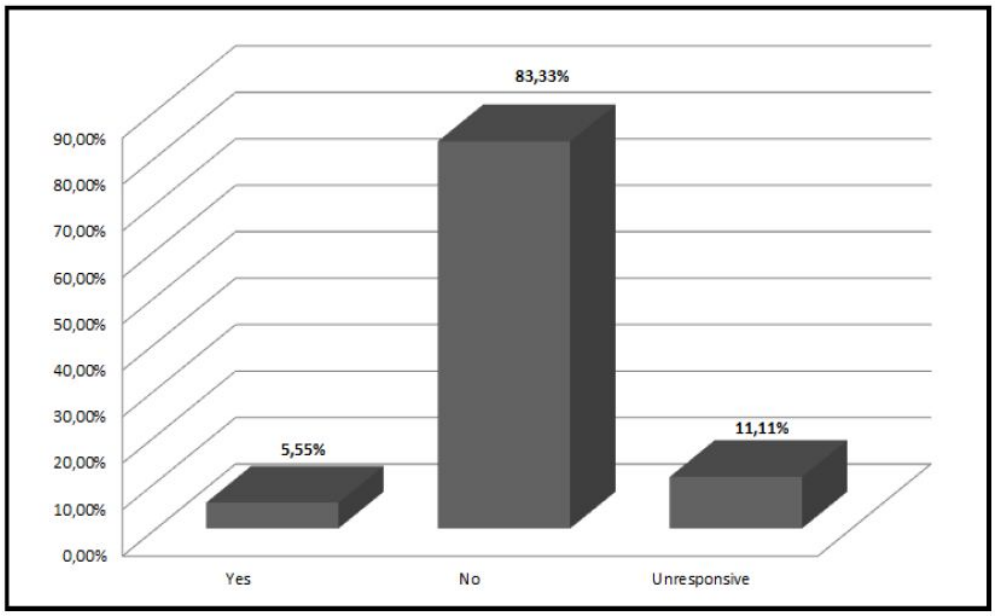

Figure 3. Have you been prepared to manage spontaneous questions?

Some of the comments are shown below:

"Not explicitly, but may be implicitly in different subjects".

"Preparation on that topic no likes that".

"I do not know that topic too much".

These comments confirm future chemistry teachers are not prepared to manage spontaneous students' questions. In addition, 72.22 % of the sample (see Figure 4) reported having no preparation about how to organize debates inspired in interdisciplinary issues for students exchanging ideas with their classmates.

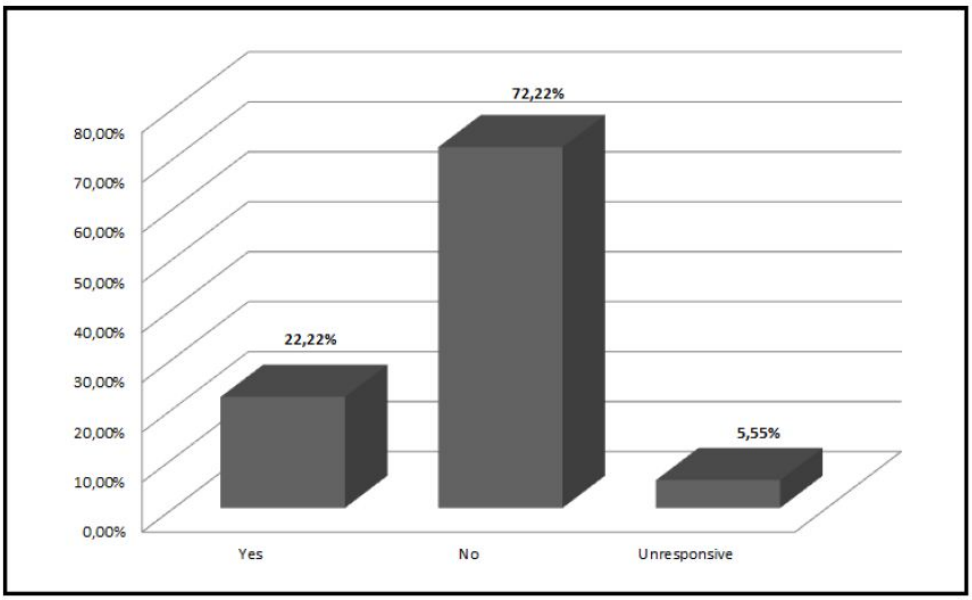

Figure 4. Have you been prepared to organize debates in chemistry class?

Some teachers expressed the following opinions:

> "Almost always looking to explore what methodologies should be followed and what kind of research and teaching must continue but not how to encourage those spaces and give them a good development".
>
> "Not specifically about this theme ".
>
> "Although exchanges of ideas are performed in different disciplinary issues there are not certain spaces for that".

Comments indicate there are weaknesses in how teachers are prepared to promote interactive situations between students in order to enhance argumentation from chemistry class. On top of that, 83.33 % of the pre-service teachers consulted (see Figure 5), considerer knowing how to argue with students must be one of the competencies required by future chemistry teachers. It confirms that although this thinking ability is not promoted explicitly in teachers training (see Table 1), pre-service teachers are conscious of this necessity that could enrich their professional development.

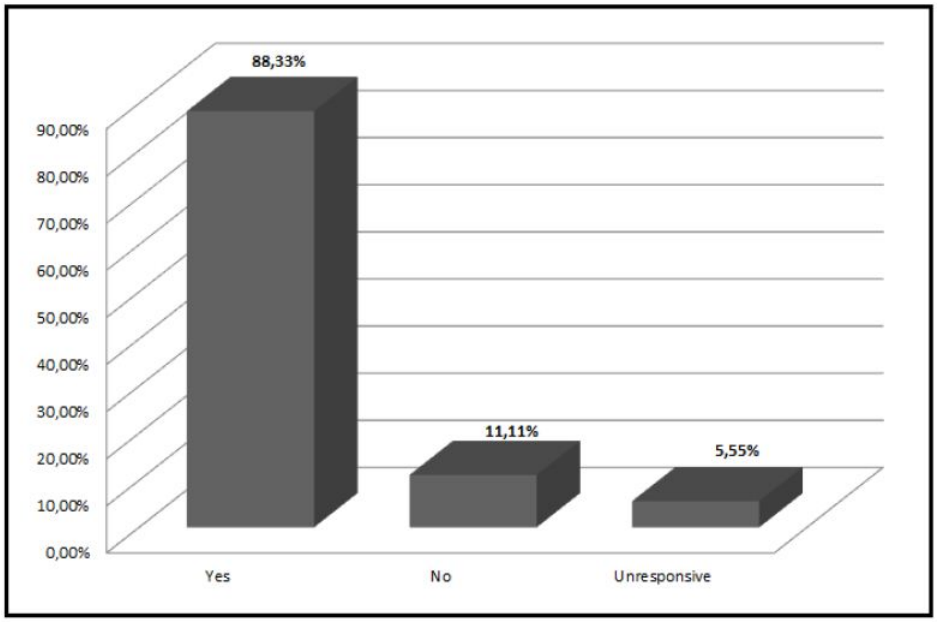

Figure 5. Is arguing with students a necessary competence for future chemistry teachers?

The third finding responds to the question: Are future teachers ready to promote argumentation in and from practical works?

Throughout the section, it is used “interchangeably the terms practical work, which is common in the UK context, and laboratory work, which is common in the USA. A precise definition is difficult because these terms embrace an array of activities in schools, but generally they refer to experiences in school settings in which students interact with equipment and materials or secondary sources of data to observe and understand the natural world” (Hegarty-Hazel cited by Hofstein & Kind, 2012:190).

All 18 future chemistry teachers consider practical work is an activity that can promote argumentation. These are some comments:

> "Because it allows a direct interaction of theory and practice so you can confirm your positions or refute them".
>
> "In addition to the scientific method about this brings the need to argue both correct and mistakes".
>
> "Because experience is good for their training".

The analysis of comments indicates that not everyone understands how argumentation contributes to the educational process. It is evident that confirm pre-service chemistry teachers are conscious of the necessity of promote students' argumentation. Nonetheless, future teachers do not know how to use laboratory work to engage students in argumentative interactions usefully.

Figure 6 shows the majority (88,88%) considers there is not only one privileged moment in chemistry education for students using their argumentative abilities. Future teachers have a dynamic representation of argumentation, they manifest this thinking ability could be promoted as long in different sections of education process.

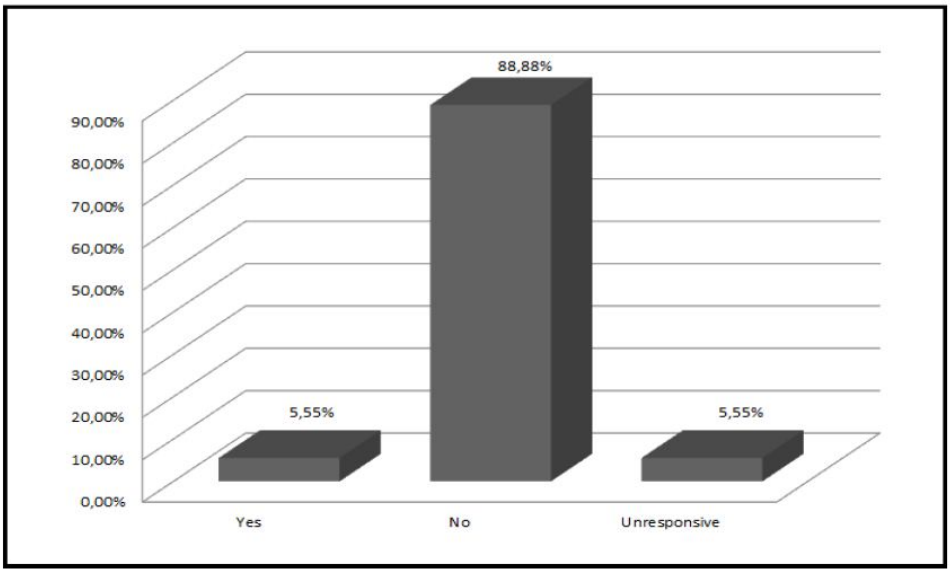

Figure 6. Is there only one privileged moment for using argumentation?

Pre-service teachers who said that there is a privileged moment (5,55%) affirmed that the topic introduction students asking questions are special periods to favor argumentation. It supports a reduction of potentialities of argumentation to help students learning chemistry through increasing their thinking abilities level.

Figure 7 was elaborated based on future teachers' representations about how to use practical work so as to promote students' argumentation.

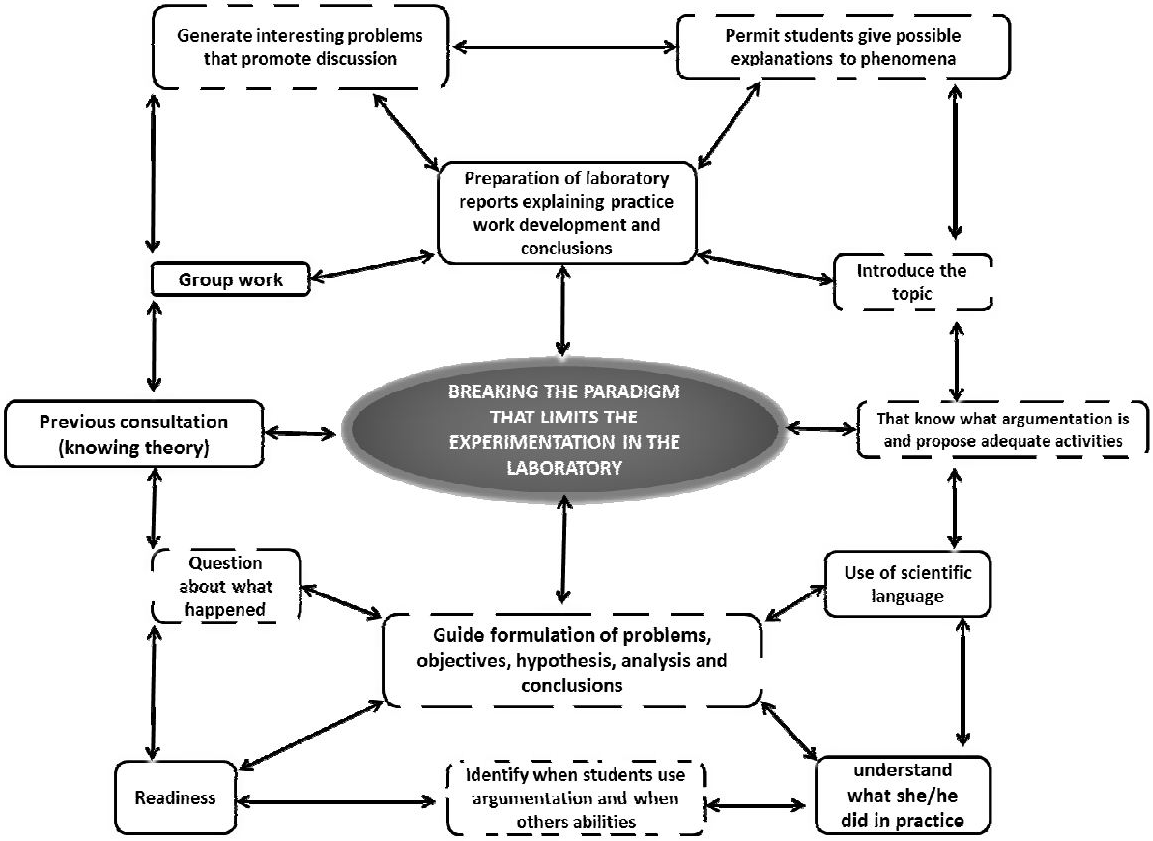

Figure 7. Elements pre-service chemistry teachers consider necessary to promote argumentation (actions done by students appear in continuous line, actions done by teacher in intermitted line and both in the centre) (Archila, 2014b:73).

Pre-service chemistry teachers' representations indicate a tendency to separate actions done by students from those done by teachers and only one linked them (see Figure 7). Several research studies (Archila 2013ab, 2014; Buty & Plantin, 2008b; Erduran & Jiménez-Aleixandre, 2007; Muller & Perret-Clermont, 2009; Xie & So, 2012) confirm that the development of students' argumentation and science epistemologies is rather complicated. It is a strong reason to include it in studies program dedicated to prepare future chemistry teachers.

Discussion

This study confirms that "argumentation is a relatively new word in science education" (Xie & So, 2012:17). It is a convenient beginning to affirm that this research had shown the importance of preparing pre-service chemistry teachers about how to promote students' argumentation. Future chemistry teachers do not know or use proper strategies to address questions to students accepting and

discussing various answers, to manage spontaneous students' questions and to use miscellaneous class activities, like practical works or debates, in order to benefit students' argumentation.

A pre-service chemistry teacher who learns to argue will more likely teach to learn chemistry arguing (Archila, 2014b). What is more, the course work reviewed during this research did not hold up strong intentions to train future teachers about how to teach chemistry through argumentation. In other words, argumentation is not a priority for the pre-service chemistry teachers program studied. This is similar to the results found in Mainland China by Xie and So (2012).

As for the design and application of a questionnaire it proved to be a rewarding methodological strategy that contributes to access written data. Thus, further studies could use this instrument. The data gathered in the questionnaire was complemented with a thorough survey of the course work offer.

Students' argumentation level depends not only on how teacher has been prepared to engage them into the progress of their thinking abilities. Nevertheless, the instructor plays an overriding role. Therefore, one of the multiple proposals of solution could be the incorporation of a module that allows pre-service chemistry teachers to build their own strategies to promote argumentation in class. That module must take into account firstly, history, theory and perspectives of argumentation. Secondly, studies of regular school practices in which the use of argumentation is and is not evident. Finally, design of adequate argumentative activities.

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