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The Importance of the History of Chemistry in School Education. Analysis of pre-service Teacher's Conceptions and Development of Teaching Materials

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Abstract To recognise the importance of integrating metascientific disciplines in the teacher's thought is one of the aspects addressed for science education reasearchers. In this study we analyse different thought factors of a group of pre-service teachers in relation to the educational implications of including the history of chemistry in their teaching sequences. Through a progressive work we identify the concordances and discrepancies between their theoretical conceptions and the development of teaching materials of a sample of pre-service teachers. We've found evidences that despite the high recognition of the educational value of including the history of science, students have few resources to generate new proposals, either because of deficiencies in their training and the lack of materials of reference and non-traditional sources.

Keywords Science History, Nature of Science, Scientific Pattern, Teachers' Conceptions, Trainee Teachers

1. Introduction

One of the main aspects to improve the quality of science education is the pre-service teachers' training, whereof deficit is situated in the disciplinary specific component, in areas such as mathematics and natural sciences. Several projects around the country have been implemented in Chile for the improvement of the Science education, also those which orientate the training of primary teachers. Thus, it appears that the cornerstone of the teacher's training are disciplinary knowledge, the didactic knowledge of the discipline and the training in scientific thinking competences (STC), something already nationally and internationally recognized in multiple studies[1] and other Research Projects (Fondecyt Project 1070795).

In this context, we assume that in science teaching the approach of scientific knowledge from a naturalized perspective is relevant[2],[3]. That is why it is necessary to acquire the language of scientific activity, which promote scientific attitudes in students, which can be achieved by teaching chemistry from a historical perspective, considering the ontogenesis and phylogenesis of each one of the conceptual nucleous of this science[4]. On the other hand, the importance of this metascientific discipline is well theoretically founded in the teacher training[5],[6]. However, we consider necessary to carry out studies which provide empirical evidences about the implications of the incorporation of this historical perspective of science as articulator axis of chemical speech of pre-service and in service teachers.

In this work the central objective is to analyze the importance that in service teachers of primary education give to the Chemistry history when they develop teaching materials to address a scientific notion in the classroom. With this aim, we took a register about the participants' conceptions about the nature and history of science. Then we presented the atomic theory through materials with different approaches: traditional- theoretical and historical, discussing with its relevance the participants. After that we developed curricular materials for the topic the periodic law.

The analyses of the collected data allow us to identify and characterize the pre-conceptions of the future teachers as a starting point, the consistency between their theoretical position and the generation of their own proposals. To further explore in the found cases typology, we chose a representative sample of participants, with whom an interview was conducted.

2. Some Reflections about the Science History and the Teachers Training

As we have stated in previous work[3],[7] it is necessary

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that the teaching practices of chemistry education enable the students to understand the undeniable historical character of the chemistry, that is, the idea that scientific knowledge "is alive" although it is written in books, that chemistry as a science is dynamic and progressively mutable, that concepts, patterns and scientific theories that constitute the chemistry framework may be replaced by others, and that the ideological frameworks in which the knowledge is based also suffer a conceptual or paradigmatic change process, which can be understood through certain theoretical principles and characterized with specific methodological criteria[8],[9].

A deep theoretical and methodological thought of the chemical discourse is necessary, because the science model defines the contents teach and didactic approach of teachers[10]. That is why when we refer to increasing the teacher's training in the discipline specific component we highlight the epistemological and didactic aspects, which are part of the various chemical teacher training.

To promote the teacher's thought we consider that the historic component in the science teacher training enable a deep *understanding of the scientific activity*, and of the theoretical models and their associated concepts; also the *possibility to establish meta-theoretical relationships* with the philosophy and sociology of science, and to value the *current scientific models* as progressive theoretical constructions from a naturalized perspective.[11]"There is any doubt of the essential role of the science history in teaching, as it *" may contribute to a less dogmatic understanding of the science and the scientific methods, and this can act as an antidote against the orthodoxy and the uncritical enthusiasm by the science*".

2.1. A Brief thought about the History of Science

It is not possible to think of History of Science in a naive simplicity: as we discuss below there are multiple ways to interpret it.

References[11] show an interesting analysis that enable us to identify the different evaluations and interpretations that can be attributed to the history of science according to how it is conceived.

It is emphasized that although the science development have always involved descriptions and historical analysis, its recognition as a *discipline* doesn't appear until XXI century. Thus, until the middle age, the scientific development involved the reference of the classical antiquity, which meant a certain *status*. During the XVI and early XVII century, history, and especially the old history, was considered by scientists from Copernicus to Harvey, as something present in the science progress. During the science revolution the history as a support in the ideological discussions would be the legitimation of science. However, during the XVII century there is a change in the role of those classical authorities, due to the Protestantism influence and the criticism of the ancient Greece scholars for being considered pagans. Thus, it emerges a relationship between science and the biblical knowledge, which previous to Ancient Greeks. During this time, each scientific discipline has gained value and authority becoming less necessary to appeal to the old time as a validation.

In the XVIII century, for Priestley and his contemporaries, the History of Science was primarily an instrument whose value was tied to the research processes carried out at the time. With the attitude to know about the discoveries and scientific advances, the History of Science took the history of progress, from a perspective linked to the *triumphalist history*, which ignores the contributions that have been overcome.

During the XVII and XVIII centuries "historic" didn't mean the same as today. A "historical" phenomenon often meant a concrete and objective phenomenon, and "History" simply referred to objective conditions, without necessarily belonging to past. On the other hand, the XVIII century was characterized by an anti-historical tendency. The Illustration used to see the History as a "weapon" in its struggle against feudalism; from a *presentist* perspective, only the recently developments deserved interest, while the past was usually considered irrational and lower. This period was characterized by a lack of historical conscience, consequence of the dominant ideas about knowledge, in particular to the Descartes rationalist ideas, for which knowledge was purely rational, a universal and non-historical abstraction.

At the end of the XVIII century, the Romantics gave a deeper sense to history based on the idea that past should be judged according to their own premises and not under the contemporary thinking as it was done by the illustrated. From that point there is a recognition to that we consider as *diachronic historiography*.

However, during XIX century, in a period of progress, consolidation and organization of Science, a distance between the natural sciences and humanities appeared. During the positivist rise of the science in the XIX century, its followers, methods and possibilities were non-historical, as they considered unambiguous and universal its methods. The historical perspective was refused and the interest was in contemporary science and its immediate predecessors, noting that history was a humanistic discipline, whose methods and objectives were incompatible with those of the natural sciences. This distinction led the History of Science to be ignored, relegating its development to the amateur scientist and historians.

For the analysis we're interested in, it should be noted that in that time the History of Science was written under patriotic interests, to highlight the nations' science. These works, initially dispersed, began to organize at the beginning of XX century, when the History of Science began to establish itself as a discipline, characterized by international congresses and conferences and by the establishment of national societies for its study.

Finally, throughout the XX century, the History of Science has become an object of interest because of its contribution to History and its educational value, and in the

recent decades has attracted increasing interest in the scientific community of historians, sociologists and scientists, and particularly in the science educators.

2.2. What History of Chemistry Must Teachers Know and Teach?

Some authors[12-16] consider that one of the main difficulties of teaching chemistry - and that these can come to be closely associated with the students low outcomes in this area - it is the transmissive, algorithmic and absolutist character in which teacher presents this discipline as a study object in the classroom. For this reason it is considered that chemistry teaching based on a historical perspective, in which the involved aspects in the genesis and evolution of the scientific concepts acquire importance in the teaching units design, enable to incorporate the problematizing character of teaching and learning science in order to change the science image that is generally socialized in the classroom not including the own historical process of science learners[17].

If science education researchers agree on something, it is that chemistry is a process of construction of the scholar knowledge with social, value, political and cultural dimensions. This idea of Science teaching with a citizenship and value orientation, enables to permanently *review* different theoretical frameworks for interpreting scientific phenomena that today *we* are explained by current theories, which continue evolving rapidly. This perspective also enables us to understand the relationship between the science and the culture of a specific time, analysing their influence on the development and consolidation of a society which shares certain values that are systematically redefined[18-21]. To provide a rational, reasonable and consistent answer, the hypothesis that we sustain is that the historical, controversial and polemic origin of the main chemistry theories, the creation process and development of the main concepts and scientific methodologies as a result of a collective work and a human construction, in which there are intrigues, tensions and distinctions, and the analysis of the complex relationship science - technology - society - communication (STSC) throughout history, with the implications of transformation of the social processes and coexistence that it has generated in general for the scientific community must be shown in the classroom[22].

Thus, it is essential to recognize the teacher's role as a mediator between the historical evolution of scientific knowledge and school science knowledge, for this reason it is recognized that science teaching and teacher training have to consider redefinition of its bases, and try to formulate new proposals, such as the science history inclusion in the teachers training, designed to enable a greater participation of chemistry teachers in the construction of their own professional and scientific knowledge.

As it has been initially stated, there are multiple ways to understand the History of Science, for this reason it is also necessary that teacher identifies the possible ways to understand it considering that there are a variety of ways to understand the History of Science, which means that each one implies an intended point of view and activities, which may pursue different learning objectives in the classroom.

To those authors[22] it is essential to consider the History as a concept to understand the impossibility to present a "totally objective" history, therefore it is necessary that, from several existing sources, possible combinations are produced with their own interpretations.

Then, there are different ways to address the History of Science such as the vertical, horizontal, internal, external, diachronic, synchronic, recurrent, biographical, prospective, among others, intentionally chosen according to the educational purpose, to address each one of the scientific theories or patterns.

3. Methodology

This study was conducted in five phases (see Figure 1), with the participation of 74 students divided in two groups, in their 4th year of training as primary teachers.

In the phase 1: we have registered the conceptions that pre-service teachers have about the Nature of Science (NOS) and the History of Science (HOS), using a Likert-type instrument, from which we took special emphasis on these two dimensions, NOS and HOS.

In *Phase II*: we worked on the scientific contents related to the atomic theory, which was addressed from two different perspectives (traditionally conceptual, TP, and a science historical perspective, HP). For each one of these frameworks we included the content thematic presentation and its associated concepts, different teaching activities and questions, corresponding to the nature of each perspective.

In *Phase III*: we developed bibliographic material, from their own production, as *"teaching units"* to address the scientific content related to the Periodic Law, which would be used in their own professional practices.

At this point, Phase IV, we did the analysis corresponding to the gathered information in previous phases, to determine if there is consistency or not, and their causes, whith the knowledge approach perspectives initially identified.

From the results found, it seemed appropriate to add a phase V, which consisted in a semi-structured interview, conducted to a sample of participants, representing all the perspective found, that is, those which maintained consistence with some tendencies, PT or HP, and those who revealed changes in these perspectives, in order to investigate the reasons why teachers had developed their bibliographic material from specific perspectives.

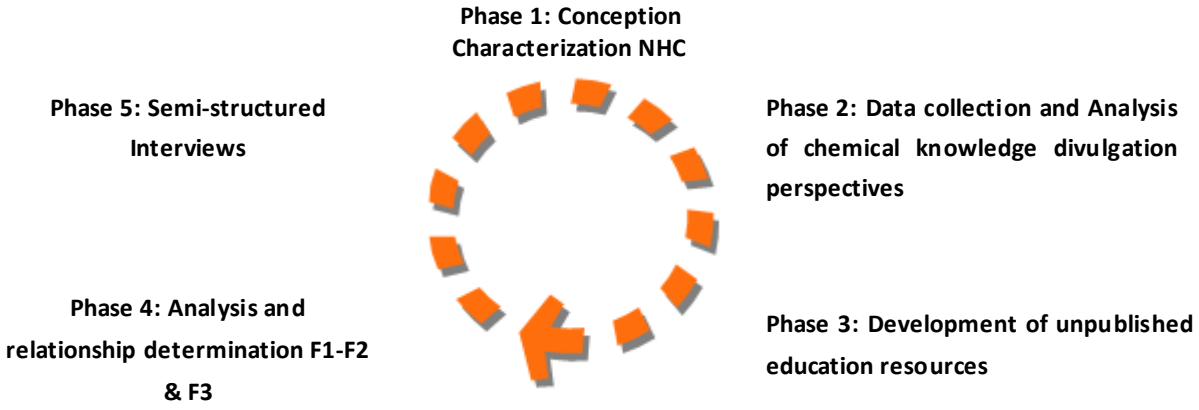
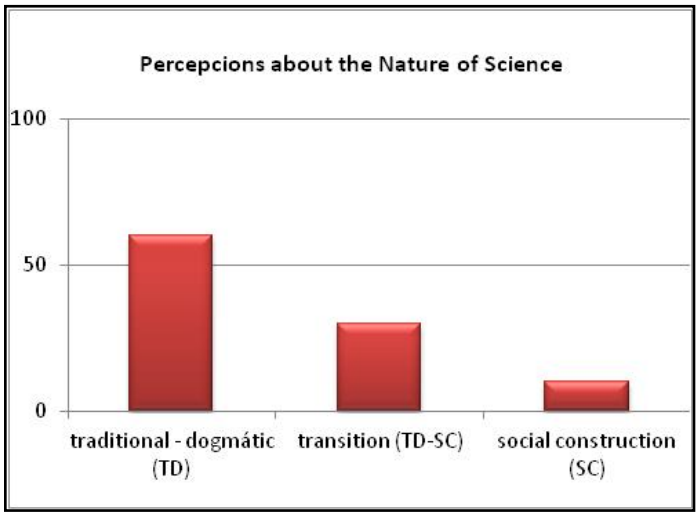
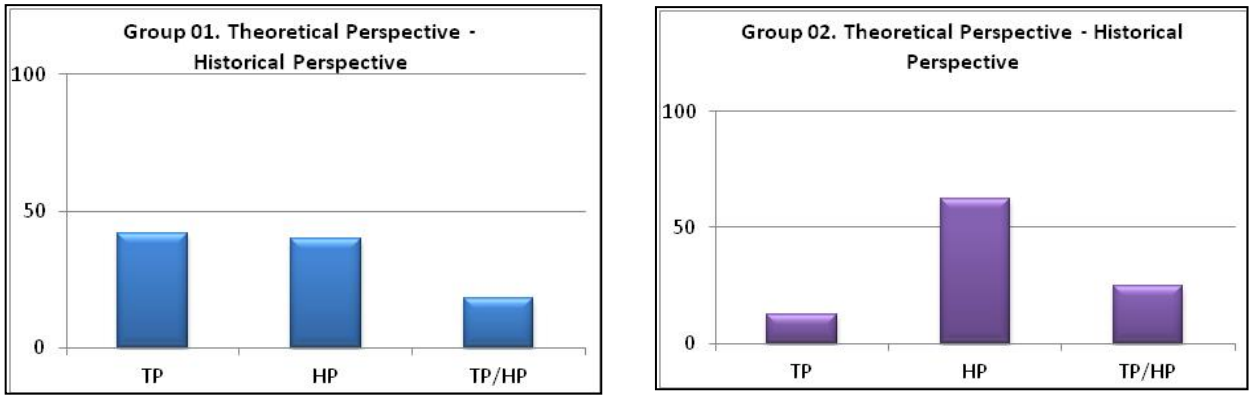


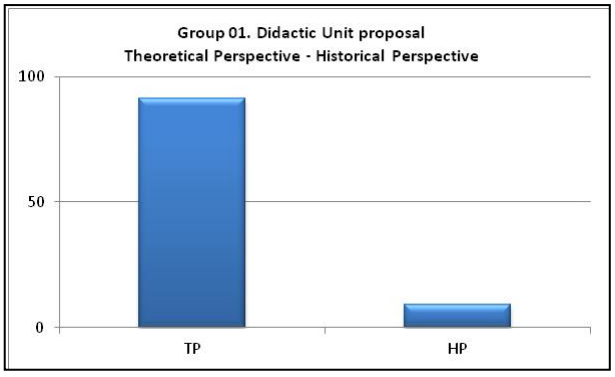
Figure 1. The different phases in which the study is based on the thought analysis and the development of chemistry teaching resources

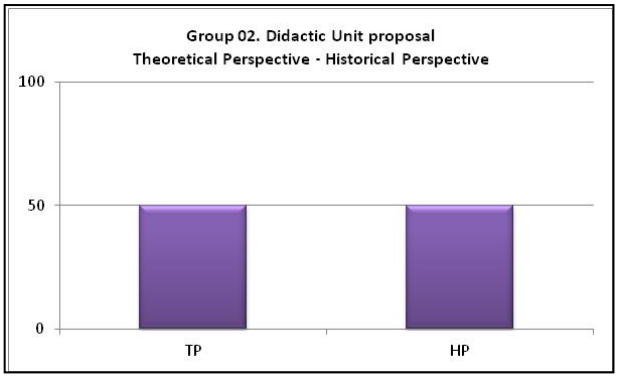


Phase 1. Characterization of science pattern by participants



Phase 2. Nomination of trainee teachers in each one of the perspectives of chemical approach considered in this study (TP and HP)





Phase 3. Development of unpublished bibliography, thematic content Periodic Law

4. Results and Analysis

We present the findings of each phase, which will permit to establish the analysis that has been gradually developed into this research.

In phase I, which refers to the conceptions that pre-service teachers have about the *nature of scientific activity* we have been able to characterize three science models: a traditional model, science as social construction and a hybrid - transition - between them.

Table 1. Characterization of the participants answers according to the nature of science dimension.

Science Pattern	Characterization
TRADITIONAL	It conceives the scientific activity linked to a scientific method, as a rigid structure which doesn't permit the use of creativity, to the construction of an objective and static science.
SOCIAL CONSTRUCTION	Science is conceived as an activity that uses a research methodology, which allows the use of creativity with a high degree of subjectivity. It considers that teacher should adopt a teaching and science model theoretical framework.
HYBRID OR TRANSITION	It is clear that they are away from science traditional vision, but they have also inconsistencies in their approaches, or unanswered questions, which could interpreted as a lack of thought.

Those results have been established within the teachers' explicit manifestation, which denotes a coexistence of different ways of conceiving the nature of the scientific activity (see Table 1) evidencing that a great number of pre-service teachers have a science traditional vision, although there is also an evolution towards a more social vision which isn't yet consolidated.

As stated on the History of Science dimension, there was more homogeneity in the participants' opinions, since for a wide majority the history of science in education may have multiple uses and benefits. It seems like the history of science can enhance the students understanding, making learning more meaningful and students have a more human view of science and its progress.

In regard to the results, there are two aspects to highlight:

There is a great contradiction with the predominant science model that we have previously found, where the science was mostly considered as a very static discipline.

The fundamental issue that represent how to incorporate the science history in the classroom is not addressed.

In relation to the *phase 2*, the "atomic theory" was presented through two different theoretical perspectives, a traditional (TP) based on chemistry books used in natural science class, and other with a historical perspective (HP). It was established that the two groups, which have a similar theoretical background (as they belong to the same training program) showed different results, as shown below.

In group 1: at the moment to ascribe to one of two positions (TP or HP), it is found that there was equivalence, being a 42% inclined to the TP and 40% for HP. There were a significant number of students, 18%, who reported the advantages of incorporating both perspectives in the chemistry teaching material.

In the group 2, 12,5 % were inclined to the traditional perspective, 62,5% of students by historical perspective and the 25% considered that both perspectives should be present in the development of teaching materials.

In *Phase III*, the production of bibliographic material for addressing this topic periodic law content, it should be emphasized that it's the time when the deep inconsistencies detected in the first phase of this study began to reveal.

91% of students belonging to group 1 opted for the traditional theory perspective (TP) in the development of their teaching units, related with the periodic law, and only 9% maintained intentions to explicitly address the historical component. It is necessary to say that we consider "biographical perspective" of science, as the historical perspective, because that was we found in the pre-service teachers production in both groups.

In group 2: 50% of the participants focused on the traditional theory perspective (TP) and the other 50% selected the historical perspective (HP). Students who had indicated the importance of presenting both perspectives were not consistent with their thinking about it.

At this point, corresponding to phase IV, the analysis and determination of the relations found in the previous phases, is presented in the following figures.

Taking a look to the students of group 1, there was a

large increase of the material production based on a theoretical perspective. Similarly, among those who had declared advantages of the historical perspective inclusion in the teaching material, when they were preparing their own material they did it without taken it into account. On the other hand the group which had noted advantages of working with the two perspectives (TP and HP) they opted for making his own material from the theoretical perspective, evidenced it in the increasing of these productions to 91% in the group 1.

Similarly students of group 2, who showed a little inclination toward theoretical perspective, when they developed their own material, they did it taking into account this theoretical perspective. Students who found relevant the historical perspective on science contents teaching, they were more consistent with it, as it was reflected in their own productions. However, as it happened with Group 1, students of group 2 who had expressed advantages of both theoretical and historical perspectives, they have opted only by the theoretical perspective in the development of their teaching materials.

In the last phase of the study, phase V, with the interviews to get information about the similarities and discrepancies obtained during the research, it was found that students, pre-service teachers, justified their development in relation to the following aspects:

There is a wide consensus that it is necessary to teach science from the lower levels of education. However, the science and the science teaching models underlying these pre-service teachers are a loosely developed, as there are important, recurrent and latent contradictions, which could be observed during all phases of this research.

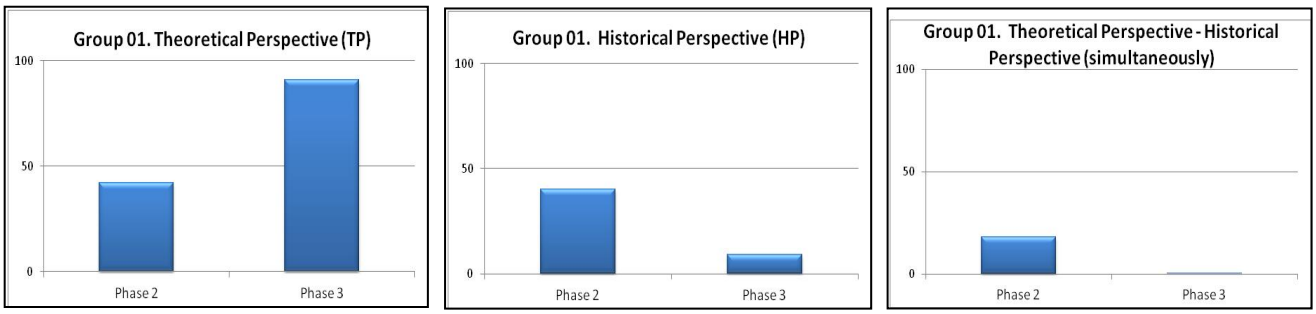
The science is considered as a human activity, which involves high levels of scientists' subjectivity, which is immersed in social, political and cultural contexts, and that tries to give answers to specific problems arising from their context. However, the development of teaching materials privileges the scientific content transmission in a theoretical way, focusing on definitions, and supporting the implementation of activities reinforcing what was presented as thematic content.

The various possibilities that teacher would have about the use of the science history are not recognized, in particular to the various perspectives in which we have characterized.

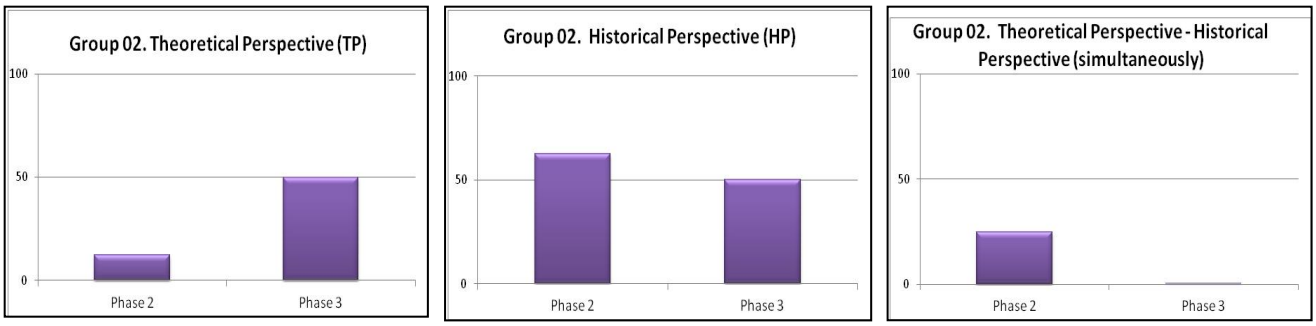
It was established once more the importance attached to chemistry books as knowledge references to teach in the classroom. Thus, it was determined that the information resources used for preparing the teaching materials presented a notoriously conceptual character which doesn't consider the history of science, which was considered as a cause of the theoretical/conceptual perspective (TP) of their productions.

5. Conclusions and Educational Implications

From the analysis of the findings in each one of the phases of this study we can propose that, in theory, for pre-service teachers, the history of science applied in their training and later teaching practice can have many advantages, related to an increase in the learning quality. Somewhat the history of science may enhance the students' understanding, make learning more meaningful, and that they have a more human view of science and its progress.



Group 1. Comparison between Phase II and the material production in Phase III



Group 2. Comparison between the findings in Phase II and the material production in Phase III

Having as reference some initial conceptions about nature and history of science, several considerations declared about the relevance of one or another perspective on the proposed materials, and production of teaching units, it becomes evident the progressive decrease of the history of science presence, that is, the progressive removal of a problematic and dynamic science model towards a model closer and closer to the tradition of the dogmatic science. In the Chilean context, this kind of inconsistencies between the teachers conceptions and their teaching practices have also been documented in in-service teachers, with similar results to those found in this study[23], which shows that these contradictions are maintained throughout the teacher's practice.

The inconsistencies causes found may be due, as it was argued by the same students in the applied interviews, the models under which they have been trained. It is clear that there are little thoughts on the science model that the students have, so it may cause that they reproduce their training style and to use as predominant theoretical references the books that they have used in previous courses. That is why it is understandable that students and teachers have a distorted view of the nature of science, its object and study method, as well as the science social impact, which can produce a school rejection attitude, against the study of different scientific disciplines in higher education level.

Despite the high recognition of the educational value of including the history of science, students have few resources to generate new proposals, either because of deficiencies in their training and the lack of materials of reference and nontraditional sources. The limited presence of the history in the materials proposed by the students hasn't allowed us to focus in a key issue which is how to incorporate the history of science in the classroom, in relation to the multiple ways of conceiving and the multiple objectives which can be addressed from each one of them. We haven't made it to the reflection, as[11], that due to the different perspectives of the history of science, certainly none of the objectives is able to cover the discipline as a whole and it may be also that from only one historical perspective all of them could not be achieved either. In the pre-service teachers' production, which is mentioned as a Historical Perspective (HP), recurrently appears the scientist's biographies inclusion, with the risk to transform it in the called *hagiography*, a white and black uncritical history where scientists become the science heroes. As it was established in the theoretical framework, there are different approaches to the history of science, but its use in education doesn't guarantee to transmit a naturalized science model, that's why the teacher must have a theoretical and methodological based training.

The dimensions that shape the teacher professional discourse, which has been analysed in this study: training models, metatheoretical conceptions, predisposition to innovation and reference sources, must be closely connected. It seems to be, and this may guide our next studies, that the own difficulties of at least one of these dimensions appear repeatedly to be the tendency to replicate the traditional science model.

In this strongly ingrained traditional model, which is the starting point for some or the model that another teachers use, often arguing teaching "efficiency" taken under the reductionist light of results in instrumental evaluative tests, we can establish that, although the possibility that history if science doesn't allow us to solve traditional scientific problems, this should not be the only aim of the scientific education, but also it can encourage students to understand in a better way the "modern science" in their social, political, economic context, etc. while promoting significant changes in the teacher's discourse.

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