Characteristics and methodological discussion about a theoretical model that introduces the history of science at an early stage of the experimental science teachers' professional formation.[1]

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Summary

We present the characteristics and methodological discussion about a theoretical model that introduces the history of science at an early stage of the experimental science teachers' professional formation. It includes context and historic information about the Chilean Educational Reform in relation to the teaching of science. The categories of analysis of the proposed model are identified and briefly described, explaining the rationale and way of introducing the history of science in teachers' professional training, insisting in the importance of a theoretical change in the models of science and science teaching that derive from the building of professional knowledge. Finally, there is a comment on various experiences developed in Chile that approach the viability of incorporating history of science in the curricula of Chemistry Teacher training programs.

Keywords History of Science, Initial Model of Science Teacher's

Introduction

In 2002 we initiated a collaboration process between our universities (Pontificia Universidad Católica de Chile, Universidad de Buenos Aires and Universitat Autònoma de Barcelona) with the purpose of to share and to improve the research and innovations that we were developing in the field of the teaching of *metasciences* (specially, epistemology and the history of science) to the present and future teachers of natural sciences of all the educative levels, from kinder to the university.

Within the didactic of natural sciences in particular, there is a full line of thinking that emphasizes the necessity to add and to link the metasciences in the processes of initial and further formation of the teachers of sciences. The metasciences allow to associate the scientific knowledge that is produced at every moment of history with the problems that it

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is trying to solve, the goals that are being followed, the conceptual and methodological tools available, and the culture and moral values present at that time[5] (5). That is the reason of the enormous importance that we give to the contents that come of these disciplines for the professional practice of the teachers of natural sciences.

Since ten years back the authors of this communication had been working in theoretical ideas and practical proposals to bring near the metasciences to the teachers of natural sciences of our countries. In the periods of doctoral formation of two of us at the Universitat Autònoma of Barcelona under the guidance of the second author, we had the chance to improve our thinking structures and actions, and to begin to share a common space of theoretical ideas that gave support to some first productions and public interventions.

The main objectives of our common project are:

1. To promote between the teachers of natural sciences of our countries, in formation and in activity, the systematic and continuous discussion about the diverse contributions that the metasciences could offer to their professional practice.
2. To develop theoretical tools to introduce in a more effective and meaningful way the metascientific component in the formation of the teachers of natural sciences.
3. To develop applied proposals for metascientific formation.
4. To confront the results of the introduction of ideas, materials and methods in the different contexts in which we worked.
5. To support the exchange of impressions, experiences and resources between teachers of our countries, so that they can to know different realities from their own ones and to improve their professional practice.

Objectives of the article

• To resume and characterize the guiding basis (or directives) of a theoretical and methodological model (MTM) to introduce the history of science in the early formation of the teachers of natural sciences.
• To incite in the teachers of sciences in formation and in activity a rigorous discussion about the scientific activity in history and its link with the processes of diffusion and teaching.
• To promote in the science teachers a permanent analysis about the development of the scientific theories in the history and the building of professional knowledge to model in classroom those theories.

[5] In this sense are of interest the next studies and researches: MATTHEWS, M. (1994). *Science teaching. The role of history and philosophy of science.* Nueva York: Routledge.; SOLSONA, N. (1997). *Mujeres científicas de todos los tiempos.* Barcelona: Talasa.; IZQUIERDO, M. (2000). Fundamentos epistemológicos, en PERALES, F.J. y CAÑAL, P. (eds.). *Didáctica de las ciencias experimentales. Teoría y práctica de la enseñanza de las ciencias,* pp. 11-34. Alcoy: Marfil. QUINTANILLA, M. (2005) *Historia de la ciencia y formación del profesorado: una necesidad irreductible*. Revista TED (Tecne, Episteme y Didaxis) Universidad Pedagógica Nacional, Número extra(34-43)

Nature of science and education

One of the goals of our common work has been to progress in the building of guiding lines that help us to add the metascientific component in the program of formation of the teachers of natural sciences. Although such integration, in the international field, it is subject of large discussions and proposals in the line of research NOS (nature of science), still is in its beginnings (Matthews, 1994).

Today, many schools and authors from disciplines of metascientific character - like the epistemology, the history of science, and the didactic of natural sciences - see science like a *human activity* of production, evaluation, application and diffusion of knowledge in an historical, social and cultural context that gives sense to the so called "scientific activity", putting the goals of the intervention that are being followed and the values that are being supported or been in game, in the communities and scientific institutions (Bordieu, 2003; Echeverria, 1995; Izquierdo, 2000; Izquierdo and Aduriz-Bravo, 2004). Due to this, on the last decades, diverse researches have insisted on the issue that the perspective of the historical analysis, *of the science and about the science* is absent of the scientific education in particular and in the teachers formation in general, in different cultural, academic and institutional contexts (Lires, 1998; Solsona, 1997). These researches of *didacticologic*[6] character conclude that the transmission and diffusion of science in the school classroom or in the university levels ignore in a deliberate way the historical happening of the scientific knowledge or at the most "show some important landmarks" when it is allowed due to the tradition or to the classic emphases of determined contents (Gribbin, 2005). Therefore, it is clear that teachers of science and scientists, as well as a non insignificant number of scientific experts in mass media, transmits an image of normative and restrictive science, far away from the cultural, social or political contexts in which scientists have contributed to the systematic, permanent and continuous development of the knowledge at the different times.

We must not forget that the different contexts or contents of science, have experienced (and they continue it doing) complex and persistent transformations as a result of the natural creation of new knowledge. Consequently, they require opportune update from the perspective of the building of the professional knowledge of the teachers of science in formation and exercise; as well as of the scientists in particular and the students in general.

The community of research and innovation in didactic of natural sciences is reaching some first agreements about what to do on the task of trying to teach the metasciencies to the teachers of sciences. Our intention is to contribute in such line, discussing about the more suitable contents and methodologies for a significant appropriation of this program component. It is in our interest, in this sense, to build some directives that could offer useful ideas to the professors of the teachers (Aduriz-Bravo and Izquierdo, 2002; Quintanilla, 2004, 2005).

[6] We speak, particularly, to the research in didactic of Experimental Sciences.

The scientific communication of the built knowledge and the hearings.

One of us has insisted on other works[7] (7), that the way that the history of science has been built and also re-understood through the centuries is sometimes ambiguous, sometimes complex, mysterious and, in some cases, inexplicably contradictory and confused on registries, methods and tools; as well as interpreted in multiple forms according to the available texts and data or legitimized by the institution or the prevailing power[8] (8) (Hackmann, 1985; Samsó, 1991). In this sense, there are many examples where this situation can be observed in different "stages" of the evolution of the theories of the different areas of the scientific knowledge. Here, we would like to emphasize elements associated to the history of astronomy (Samsó, 1991), the history of the optics (Tissandier, 1887), the history of physics (Gribbin, 2005), the history of chemistry (Left, 1995), the history of the medicine (Crombie, 2000) and the history of the genetics (Marantz, 2000) to name only a few some clear examples on this matter.

At this moment it is not known all about what we would hope to know (and in the way that we would hope it) about which is an *historical fact of science*, in an accurate way, according to the present conceptions. There are moments in the different cultures where the science is only a rhetorical process without great theoretical achievements, and where their major goal is only to get some social, cultural, religious and even politic acknowledgment tied to the social control of the dominant classes as Shapin shows with regard to the Techno-scientific Education in the Victorian England of century XIX[9]:

> ...Our interpretation provides an integrated explanation of the relationship between the Institutes' original control purposes and the nature of the scientific knowledge presented in their curricula..."

It is almost evident in the discussion that we are beginning, the enormous value of the language and the ways of communicating and diffusing the history of science in the different context: schools, professionals, or political-institutional. For example, without going further away, for Sthepen Shapin (and although, of course, this it could be controversial in his levels of interpretation) in the England of John Dalton, century XIX, it would be promoted a conception of the science in which it is confused with the philanthropy of the bourgeoisie and the scientific education of the working-class, with the excuse to reduce or to prevent the social destabilization in front of the progress of the revolutionary ideas derived from the industrial development and the new capitalist economic order questioned by Engels and Marx [10]. Particularly, the zone of Manchester (near Eaglesfield where Dalton was born) was characterized by the progressive consolidation of the Industrial Revolution (initiated towards 1760), whose main characteristics were: the adaptation of new technologies, the gradual reduction of the agrarian exploitation system, the regional productive specialization, the increase of the

[7] From the autor and collaborators, Quintanilla(1999, 2001,2002 y 2004)

[8] To read the interesting analysis about the Illustration Science, chapter 3, in the book of Gribbin,J.(2003) Editorial Crítica.

[9] In: S***cience, Nature and control: interpreting Mechanics'Iinstitutes***. *Social Studies of Science*.vol 7 (1977) 31-74(pp 32).

[10] For further deepening in this issue, see Shapin & Barnes (1977)

economic growth derived from the industrial diversity, the increase of the capitalist bourgeoisie and the systematic and progressive reduction of the mortality ratio[11].

As a result of this, it is possible to anticipate that the different publics of the science, students, teachers, experts and common people, would have a deformed view of the nature of science, their subject and method of study, and about how the scientific knowledge is built and how it evolved, and ignore their social repercussions, which in some moments, maybe in the majority, it raises an attitude of rejection towards the scientific matters and make difficult their learning and understanding, specially when the idea is only to reduce to axioms and formulas the scientific language, that it requires, more than that, of a process of evaluation and complex interpretation of the theories, of the instruments and of the phenomena that had been studied throughout the time and under given theoretical and philosophical assumptions (Baraona, 1994; Perez, 1998;Uribe & Quintanilla, 2004). Moreover, and as Bordieu raises (2003), the rules of the scientific method as they are explained by the logic experts do not correspond to the reality of the practice, promoting an idea of a closed scientific community whose research talks about a narrow fan of problems and whose *paradigm or disciplinary matrix*[12] is accepted by an important fraction of scientists and that it tends to dominate itself all the others.

The absence of the history of science in the teacher's formation

Most of researches in this field (Solsona, 1997; Lires, 1998), agrees in diverse causes or factors that would explain, to a great extent, the ignorance of the history of science (HS) in education and in the teachers formation (and also scientist formation). Among them they stand out:

• The almost total nonexistence of the H.S. in the school contents of the plans of secondary education and in the majority (if not all) of the university programs of formation of the scientific careers.

• The persistence of a dogmatic, neopositivistic, utilitarian and instrumental conception of science, dominant paradigm in the teaching institutions and in the research in basic and applied sciences.

• The persistent lack of interest of teachers and scientists to assume "the analysis and the thinking" of the historical events like a part of the class of science and the professional formation, preferring the formalization and the algorithmic treatment of the immense majority of the scientific contents, still in the case that are essential to do it.

• Few publications in the area of history of science and teaching, which makes difficult the access to sources, documents and systematizations of quality in particular topics in specific fields (genetic, cytology, hematology, chemistry, to name some).

[11] Pellón, I (2003)
[12] The signaled is Bordieu himself (2003) *el oficio del científico,* Anagrama, Barcelona (pp 34)

• Despise of the history from scientists and teachers of science, who see it like "point events" disconnected of the contents that "must to be taught" and by which *the society would evaluate the capacities and competences* of the students.[13] (13)

Indeed, we have an *inherited conception* of science with a successful character, whose protagonists are "few privileged people" creators of theories, experiments, machines and instruments, whose unique works have separated during decades the "socially built" scientific speech from the cultural contexts where it has been produced and developed (Grandson, 2005). Still more, in the Encyclopédie francaise of 1939 three fundamental differences between the science of the experts and the so called "profane" public were settled down: differences of world, language, and style, and that in the end would constitute an incommensurable division (Bensaude, 2000).

Description and theoretical aspects of the developed model

Our more recent conceptual formulations, than serve as foundation to the design of interventions for formation of the teachers of natural sciences, include, for example, *the guiding basis to incorporate the history of chemistry in the teachers' initial formation* proposed originally by Quintanilla (2004) that we have reorganized in the Fig.1. This scheme serves as a base for an empirical study that is the subject of another initial research[14]. This cycle of ten stages incorporates the following ideas for the research in didactic of the sciences[15] (15):

1. That the formation of the teachers of natural sciences has to be in sciences but about sciences too, that is to say, has to have a strong metascientific component.
2. That this metascientific component strongly interacts with the other knowledge (scientists, pedagogical, psychological, and didactic) of the teachers of natural sciences (Bromme, 1988).
3. That this component is the base for the didactic transposition.
4. That this component results from a very thought process of selection of some contents coming from the erudite metasciences, those that have value for the professional practice of the teachers of natural sciences.
5. That this component must to be built from the understanding of science that already brings the teachers to their formation.
6. That this component serves to multiple purposes in different levels of concretion.
7. That this component must to be built anchored in the didactic and scientific knowledge of the teachers.

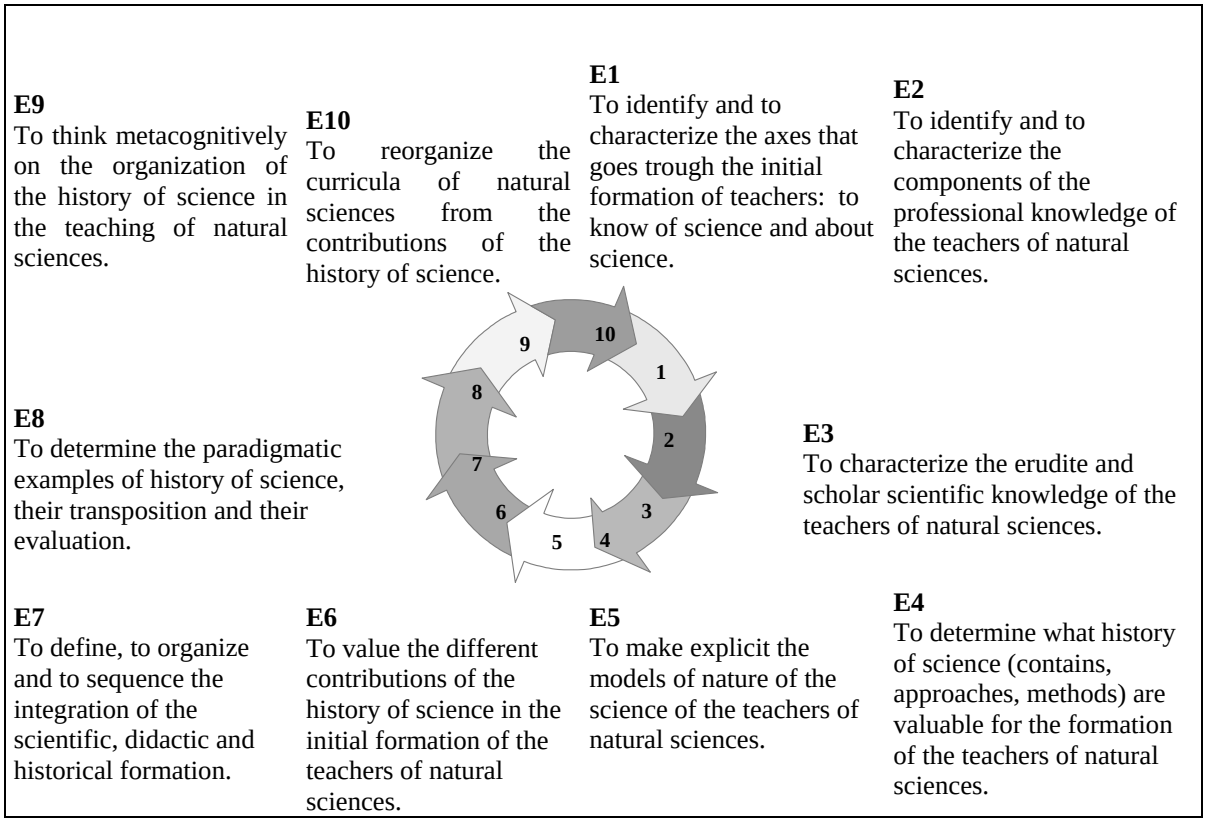
[13] In this sense the topic of evaluation takes us to an interesting debate. We has worked this with doctor Alberto Labarrere. We suggest to read the article *La evaluación de profesores de ciencias en formación: un enfoque desde la profesionalidad emergente, la posición social y la representación de los conocimientos y modelos teóricos*.(Labarrere & Quintanilla, en prensa)

[14] *Desarrollo de un instrumento de evaluación para discriminar los criterios y categorías del uso de la historia de la ciencia en la enseñanza* (Merino & Quintanilla, Actas del VII Congreso Internacional en didáctica de las ciencias, Granada, España, 2005)

[15] These issues had been properly presented in ADÚRIZ-BRAVO, A. (2001). *Integración de la epistemología en la formación del profesorado de ciencias.* Tesis doctoral. Bellaterra: Universitat Autónoma de Barcelona. En línea: http:// www.tdx.cesca.es/TDX-1209102-142933

8. That this component must to be taught through *paradigmatic examples*, meaningful and powerful, for the teachers of sciences.
9. That the teachers have to become to be able to control that component.
10. That this component can transform with depth the way in which the teachers design the curricula of natural sciences in their classes

Figure 1. Stages of the theoretical and empiric cycle (TEC) tending to incorporate the history of science in the initial formation of the teachers of natural sciences.



Brief characterization and purposes of the stages of the model

In each one of the stages of the cycle historical and didactic texts are introduced to help to reach the diverse goals. For example, in stage 10, the teachers of sciences uses the history of science to identify fundamental concepts and *irreducible models* that they will select like the most important ones to build a program of natural sciences very epistemologically based on the educative level in which they evolve.

The instruments created from this cycle have the goal to help the teachers of natural sciences in formation to think on the contents, instruments, objectives, situations, procedures, values, approaches and materials that would allow them to value the contribution of the history of science in their own professional development. The ideas that we are discussing in our work group, that they give rise to conceptual marks like the cycle presented here, serve to us to support practical proposals that we are beginning to test (Izquierdo and Aduriz-Bravo, 2004). Briefly let us see each one of the stages.

1. To identify and to characterize the axes that goes through the initial formation of the teachers: to know of science and about science

In this view of the construction, reconstruction and deconstruction process of the historical fact of science, the actions that are important for the pedagogical, epistemological and didactical intention, have relation with identifying and characterizing the axes that cross the initial formation of the teachers: to know of science and about science. We must insist on the fact that the initial formation (and also the permanent one) of teachers of experimental sciences is sustained basically in the systems of beliefs or social representations that the teachers have about their subject of knowledge and the nature of science that they teach; and where coexist in a persistent and intuitive way, traditional, dogmatic, simple, little elaborated and unstable meanings, the most of the time ambiguous, that terms and even determines the processes of teaching, evaluation and learning of scientific knowledge. In this sense, we have insisted on the necessity to progress towards more complex and holistic representations of the nature of the science and the building of professional and historical knowledge, in which the activity of the teachers of science in formation is described and analyzed in a more comprehensive and broad way, to the same time that the "scientist" would be conscious of the epistemological model of science and of the model of teaching of sciences that produce these directives in relation with to promote the bond between the history of science and the solution of "present" problems of the scientific theories.

2. To identify and to characterize the components of the professional knowledge of the teachers of natural sciences

In an apparently natural way, it is common to imagine the process of professional and scientific construction only like a confrontation of the student with the theory and its test (experiences, procedures, instruments, contents, etc). In this confrontation (stressing, the most of the times) the teacher of science in formation tries to penetrate more and more deeply in the unknown facets of the situation, tries to get a better understanding about what is the problematic situation raised and to find the most useful instruments, than would allow him to have access to the answer prefered "by the training scientist". In this sense we had been working the idea of the "planes of the development" that connect in a very good way with the necessity of to put the analysis of the history of science in a naturalistic direction that properly surpasses the pure instrumental ranks of the content, as well as of the professional knowledge and favors in the teacher in formation, the sense that has the building of the scientific knowledge at certain time or culture. In our specific proposals[16] (16) of initial and continuous formation of science teachers we distinguished three fundamental planes in the presentation of scientific problems in the classroom: the instrumental-operative plane, the personal-significant plane, and the relational or social plane or cultural plane of transference.

[16] We has deepened in this theoretical and methodological frame in the article *La solución de problemas científicos en el aula. Reflexiones desde los planos de análisis y desarrollo.* Revista Pensamiento Educativo Vol. 30. Facultad de Educación PUC. Pp.121-138. ISSN 0717-1013. Labarrere, A. & Quintanilla, M. (2002)

3. To characterize the erudite and scholar scientific knowledge of the teachers of natural sciences

In the task of to think about the ways of historical building of the knowledge in general and experimental science in particular, it becomes necessary to understand and to interpret not only the "scientific tradition" with its contributions, structures and logics of building, but something more. We appreciate the cognitive view of the scientific knowledge that considers a different reading of the nature of science, its method and purposes; largely developed and diffused in the last decade by diverse authors and researches and that it becomes a nearer alternative to the science which we taught or scholar science (Giere, 1998; Izquierdo & Aduriz-Bravo, 2003). This view emphasizes the importance of the nature and meaning of the theoretical models that are taught, of the scientific activity in the context of the education, the languages of science, the ways to reason it and the ways to communicate it to others.

We insisted on the necessity to distinguish a science of the scientists and a science of the teachers of sciences. In this sense the dominions and planes of analysis of the content will have to respond to the *didactic of a model* that confronts these scientific dominions and distinctions with the deepening and complexity levels that are inherent to it. The erudite knowledge has a structuring theoretical frame (STF) and a disciplinal specificity (DS) that must be translated in a scholar scientific knowledge. In this sense, the model of initial formation of teachers that includes the history of science, necessarily must imply that the *trainer of the ones that will train* must develops in the early professionalism of the teacher of sciences, the central idea of *to think with theories* and he must to think its daily pedagogical practices with models and categories of comprehensive analyses that favor the right direction of the taught scientific knowledge, verifying the implications that these models or theories have had in the history of the scientific education and that has structured it with certain epistemological purposes that require to be boarded and understood again (Duschl, 1997; Fouréz, 1998; Klimovsky, 2001; Perez, 1998).

4. To determine what history of science (contains, approaches, methods) are valuable for the formation of the teachers of natural sciences.

The dynamics that can be established in this sense takes an indefectible value, as it is to assume that in the history of science, the theories, the phenomena and the instruments to appropriate it and to communicate it, goes further the registry of the "scientific product", to settle in a dialogue between the man and the world with human purposes. It is necessary to emphasize to the teacher of science in formation the fact that there are "different times" from the history of chemistry and diverse sources to approach it, to know it and to interpret it. For that reason, it is reasonable that the called *stages of the history of science* (of the different disciplines) could be analyzed from a general reading of the knowledge (for example, science in the old civilizations; science in the Renaissance) and from a particular reading (for example, the paradigmatic facts since XVIII century). It becomes necessary to have the availability of a specific literature that it gives "scientific narrations" that allow the counterpoint, the discussion and the analysis of the first, second and third order of the historical content which it is taught and of the specific public that receive it. In the same

way, to introduce in the formation of the teachers, polemic aspects in the history of science that provide with interpretations about the political paper of the institutions, the minorities, political elements, ethic aspects and of genre that raises new glances on the historical and evolutionary construction of the scientific fact as well as its learning and teaching (Solsona, 1997, 2003).

5. To make explicit the models of nature of the science of the teachers of natural sciences.

An initial formation of science teachers that consider the complex connections between the genesis of the object of knowledge, the nature of science and the processes of teaching-learning of itself, will have to promote a thinking and comprehensive process, in which the building and formalization of the scientific knowledge and its teaching, acquire a metadisciplinary character of knowledge which given their epistemic nature are in a permanent crisis and change, in other words, where the teacher is learning to teach science and the student learning to learn it (interpretative-critic and mutable view of the knowledge). It becomes necessary then, that the teachers of science in formation, do make a theoretical meditation about the nature of science, specifying their previous ideas or implicit theories and showing the definitions that they gives to their methods, instruments and purposes. Of course, these meditations are focused in a model of initial formation that appeals to an analysis of greater hierarchy, depth and formalization, according to the professional stage in which are the teachers and the ones who favor the modeling of this knowledge.

In synthesis, it is necessary to discuss insistently the representations of science and teaching of the science that the teachers have, confronting the ideas about the knowledge assumed with certain epistemological categories and showing the complexity of the scientific theories, its method, its language and its instruments.

6. To value the different contributions of the history of science in the initial formation of the teachers of natural sciences.

The historical discussion of the evolution of the scientific knowledge can provide elements and methodologies of analyses that allows the re-understanding of the scientific contents, their genesis and teaching (Uribe & Quintanilla, 2004; Cuellar, L.; Perez, R. & Quintanilla, M., 2005). Also, this understanding can contribute with new ideas about science and its progress, since many discoveries have a specific initial foundation that flows toward a second or third order analysis. So is case of biologist Gregory Mendel(1822-1884), whose contributions to science have been source of numerous and significant works in the history of the genetics, that actually leads us to molecular chemistry, unthinkable in his time and that when taught at the school, is reduced to the statistical algorithms (Alzogaray, 2004; Marantz, 2001; Quintanilla, 2004 a).

The idea of historicity of science in the professional formation and teaching can positively influence in new attitudes and representations about the science and its methods of production (Saffer & Quintanilla, 2004; Quintanilla, M; Left, M. Aduriz-Bravo A, 2005). We assumed that science is a process of building of knowledge with dimensions not only historical, but also philosophical since it is the product of a complex social activity

that precedes and follows the individual and cooperative act of the discovery or the creation and justification of the new knowledge. Reinforcing the previous diagnosis, it raises to us the necessity to appreciate a work in didactics of sciences that deepens in its sources, since it allows to link the conceptual weave that have formed and the problem that is tried to solve in the history of science (Left, 1993). This form of work allows to evaluate conceptual frames different from the present ones, used to interpret scientific phenomena of also different times that today we understand well and which would be explained by means of present theories (Estany & Izquierdo, 1990; Papp, 1996). It also helps us to know the relation between science and the values of a culture, of "specific moments" of the history of the humanity and to understand the influence of sciences - of a style of understand- in the development of a society (Left, 1993.1995).

7. To define, to organize and to sequence the integration of the scientific, didactic and historical formation.

We thought that in the processes of early formation of the chemistry teachers it is required a robust and coherent conjunction of three basic nuclei: the historical one, *didactic* and the *scientific*, to develop the professional that is requires, successfully operating in the different realities of the educative system from the point of view of the scientific learning and the educational formation. We will briefly spoke about each one of these nuclei and the relations that is necessary to establish among them:

• **Historical Nucleus:** theoretical and methodological development of the models that interpret history (diacronism, presentism, anachronism, etc.) and its application to the design of specific didactic units;

• **Didactic Nucleus:** re-understanding of the didactics like field of knowledge and research that rescues with educative sense the disciplinal content and its epistemology, based on theoretical models, models of action, and models of specific phenomena;

• **Scientific Nucleus:** handling and righteous empirical and theoretical direction of the organizing concepts of chemistry (particle model, model of chemical change, concept of substance, to name some) from a reading of naturalized science that requires evidently certain levels of formalization, according to the type and emphasis of the scientific content.

In Chile, the little researches made to the date in the field of initial and continuous formation of science teachers, give account of the little assuming and conjunction of these three basic nuclei that constitute the profession, therefore, exists an empty niche of high interest and great repercussion for the reorientation of the processes of formation of trainers (Quintanilla et als, 1999, 2000). It seems to us that the Model of the Three P is an interesting contribution in this sense, since it recognizes the interdisciplinary character of the didactics of sciences and gives consistent directions of how to organize in different levels, the analysis of the scientific discipline and their teaching with other essential components like the psychological one, the historical-epistemological, the curricular and the cultural one (Aduriz-Bravo & Izquierdo, 2003).

8. To determine the paradigmatic examples of history of science, their transposition and their evaluation.

Therefore, we suggested working with examples of paradigmatic episodes in the history of science, thinking over each model the consequences of its teaching. It is possible to use strategies of different type as the ones we indicate at the end of this work. The coordination between the "scientific knowledge built in history", the transposition of the knowledge taught in the class of science and its evaluation, requires a way to imagine the world that must be coherent between the theories and the phenomena. Therefore, the **didactic sequence** must incorporate in the cycles of learning the rightly argued theoretical modeling, giving spaces for "thinking how to teach" specific contents that could promote a nonfinished understanding of the nature of science, their phenomena, methods and tools for the search of new knowledge. These sequences will have to coordinate the plan programmed with emergent events and to use pedagogical devices that based on metathinking, would provide the teacher in formation tools, strategies and directives for the theoretically based didactic design. Under this view some question comes up, like the following ones: Which ones are the facts of the history of science more appropriate so that the professor in formation could elaborate a theoretical model through the different activities of learning, the formal instruments of evaluation, and the images and symbols that the historical episode shows? How to give to a righteous beginning to the theoretical thought of the students and to know which ones are the most correct proposals to relate the historical phenomena of science to these models in the class? Which are the strategies of evaluation more appropriate to make possible the construction of those concepts doing that the history of science comes to be a mediating instrument between the science of the scientists and the science that must to learn to teach our teachers? In this sense, it is of interest the use of analogies and metaphors that, having like center the argued speech on the basis of theoretical models, defy the creativity, the imagination and the auto-controlled learning (Izquierdo, M. &, Izquierdo A. 2000).

9. To think metacognitively on the organization of the history of science in the teaching of natural sciences.

The center of our theoretical argumentation is based on the fact that to promote and to praise the continuous and progressive development of the scientific thought throughout the history and the building of professional knowledge of the teachers of science in formation, it is necessary to consider the importance that acquire their implication in evaluative situations and activities; that through directed strategies to promote the systematic participation of the students in the evaluative contexts with the progressive and complex development of its professional identity and sense of belonging to a group. On this issue there are no studies in Chile that would allow to strengthen the evaluative practices like a process to teach to think to the students with theory the facts of the world and to develop in them the motivation and the interest to study the science from an historical point of view at a level of professional formation.

We must remember that sciences have a rhetorical and arguing nature, often defined by the scientific authority of the moment or the agreement of their communities, where the

explanations and interpretations have produced different meanings at different moments of the history. The questions that the scientist makes to himself can also be change and redirected, according to the purposes of who asks, since the intend of a historian is to try to penetrate in the mind of the subjects, in order to catch his problems, values, expectations and hopes in front of the uncertainty of an unknown future, raising questions to the primary or secondary sources with an intention different from the philosopher whom it looks for in the permanent historical substances of the scientific thought or the social or individual behavior (Baraona, 1994; Crombie, 1993, Izquierdo, 1993). If chemistry teachers, for example, to make to think to the teacher in formation: what political events happened in France at the time of Lavoisier; what he thought of chemistry, what we know of its personality? Why he dies guillotined?

10. *To reorganize the curricula of natural sciences from the contributions of the history of science.*

The goal of our idea is that the teachers of science in formation and also in exercise understand the complex routes of building of the scientific knowledge and the consequences that this has brought for the teaching, the evaluation and the learning of scholar science, reckoning the importance of relating the knowledge of the discipline to the history of science and the didactics of sciences. In the same way, to demystify the experimental practice like the only alternative to learn science from a positivist view and to propose different options linked to a moderate rationality for to think, to do and to narrate science in the school (Izquierdo, 2000; Quintanilla, 2002). To imply to the teacher in formation in the analysis of scientific text and the ways to communicate the history built at different times and contexts. It is of special importance, that he could have new elements to take a theoretical position in front of the scientific knowledge that he must to teach in the school, although this science could "written" already.

Some preliminary results

In Chile, particularly in the Department of Didactics of the Faculty of Education of the Pontificia Universidad Católica de Chile, we have introduced the issue of the history of chemistry working with different **tools, historical contents and methodologies** to achieve it.

• The used tools: Didactic Memory and the Heuristic "V"

The **Didactic Memory** (DM), incorporated in our Model, is not only a document (product), but the tool-strategy (book of discussion and analysis) of production and transformation of the inferences, analysis, generalizations and proposals of intervention of the teacher; in fact, the DM can appear like document and in addition like rebuilding process of the formation history of the person through the activity of metacognitive thinking of the teacher in formation, who represent himself on his production and it turns it, intentionally, in instrument for his own change; in other words, to make evolve or strengthen his representations about the history of science, the evaluation, the transposed science, the students like subjects, on himself, etc. In the same way, the V de Gowin or ' Heuristic V',

has turned out to be a strategic method to help the teachers in formation to understand the structure and development of the professional and scientific knowledge and the forms that have the human beings to produce, to spread and to transform it, indeed, is a metacognitive-heuristic instrument since it is used like aid to solve a problem or to understand a procedure (Novak & Gowin, 1988). When the V like heuristic resource is used in a learning-evaluation activity, the professionals and investigators in formation are helped in the task of to recognize the existing interaction between which they already know and the new knowledge that are producing and trying to understand from their particular points of view. As a consequence, the metacognition and the thinking are in the central place, understanding them like knowledge of the student on their own processes, the historical knowledge and, overall, like the access to the control and conscious regulation of their cognitive activity in the development of the DM. This strategy of construction of knowledge and evaluation of the professional development of teachers has been applied in the undergraduate, the continuous formation and the post degree of the Faculty of Education of the PUC from 1998 to the date in the areas of experimental and mathematical sciences, in addition to other areas such as history, geography, art, language and Literature, being high valued by the students. Some of the works made by the science teachers in formation, are resumed in Table 1

Table 1 Products elaborated by teachers of science in formation linking the history of science with the didactic sequence and metacognition

Scientific area	Title and worked historical content
Inorganic Chemistry	History of the Acid-Base Theory and its teaching.
Organic Chemistry	From carbon to vital polymers.
Genetics	Contributions to introduce the history of the genetics in secondary education.
Natural Sciences	The teaching of the Theories of the origin of the life.
General Chemistry	From Democritus to Einstein.
General Chemistry	How to teach the evolution of the Atomic Theory?
Mathematical	The history of the "zero". Design of didactic units.

In addition we had been developing products that are in harmony with the courses of *didactic and epistemological modeling* in the initial formation of chemistry teachers. The reader will be able to find specific references in the bibliography of the chapter that we indicated ahead.

• *The contents on history of chemistry*

In the same way, we have promoted advanced courses with different emphases and public, developing, among others, the following subjects: Origins of chemistry, History of the acid-base theory; the chemistry in the old civilizations (Greece, Rome and Egypt), History of chemistry until the XVIII century; History of chemistry from middle of the XVIII century to the present and Introduction to the thermodynamics and the evolution of the Atomic Theory. These contents have experienced complex and persistent transformations as a result of the natural creation of new scientific knowledge in the discipline. Consequently, they require of an proper update from the perspective of the building of professional knowledge of the teachers of science in formation and exercise.

• *The used methodologies*

For it the contents of each one of these units are introduced indicating the scientific literature and methodologies of analysis and discussion of the organizing concepts (chemical change, substance, element, compound, among others) and the pedagogical, didactic and scientific directives of how to build the Didactic Memory gradually leading the theoretical model (MTM). In order to favor the understanding, creation and teaching of these scientific knowledge from an historical reading that includes this model of formation we thought in an active proposal in which the teachers designed and experimented in a cooperative way materials, experimental practices, analogies, observation guides, field guides, among others, incorporating the discussion about the history, the philosophy and the didactic of sciences in each one of them.

According to this it would be possible:

• To explain contextual histories, that could be used from a didactic point of view: in order to introduce concepts, to motivate, to promote some attitudes, to associate knowledge of different areas, to justify inter-disciplinal activities, to help to unitarily understand the teaching of the different disciplines (scientific and nonscientific).

• To make simulations or theater of historical situations, of debate in which the students can argue. For example, in the case of "rival" theories, a group of the class will be in favor of one theory, whereas another group will defend the ideas, let say, the "opposite" ones.

• To repeat important practices, let them to see which ones were the scientific ideas in the time that were postulated, the possibilities of interpretation that were available and the utility of the same ones, going further the boundaries of an analysis centered in if "they were truth or they were not ".

• To identify and to describe to old tools with pictures or schemes from reproductions or sites in Internet. To discuss about the materials with they were elaborated, how they were propagated, what were their contributions, what ideas that provoked or what controversies they attenuated, etc.

• To read historical texts specifically selected (as it is done in the Literature class) making see that the books always are written thinking about who is going to read them and that reflect the values and culture of a time. It is not required great bibliographical sources, nowadays it is possible access to images and original texts of great scientific quality

• To present historical personages who allow to understand to the students the human aspects of sciences and the set of values (individual and social) in which they are developed and that normally they do not appear or are attenuated in the text books. For example, always did they have resources to research? If it was no so, how they did do it ? What personal problems conspired against that their studies were taught or propagated?

• To show historical situations of crisis and doubt that could promote in the students the idea that the scientific knowledge is not a dogma nor a history of good and bad scientists.

• To promote the analysis of historical-political, historical-geographic, historical-social or historical-economic "frames" which they favored or not the development and spreading of science, its problems, instruments, etc. For example, why the ideas of Galen predominated during so many centuries? What factors made that Servet was accused of heresy and their books were burned?

Conclusions

Our innovations intend to contribute to improve the quality of the program of initial formation of the teachers of natural sciences including an important metascientific

component that it promotes a more thought and auto-controlled style to teach sciences. The innovations that we propose require, in the medium term, strong institutional options to redesign the programs, the administrative structures, the models of formation and the sense that is being given to the teaching profession, as well as the materials and activities of work. In the short term, our proposals can be implemented, as it is becoming in our three universities, within the traditional courses of didactic of natural sciences and in an optional or complementary offering[17].

Nowadays we are working in the design of complete courses centered in the contributions of the metasciences to the teaching of natural sciences and in the production of practical materials to incorporate topics of epistemology and history of science in the initial and continued formation of the teachers of natural sciences. At the same time, we went on working in the formulation of theoretical models to support these proposals. Many of our materials already have been published and they are being used in our countries, although on scale rather restricted.

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