Please cite the source as:

Barona, C. Verjovsky, J., Moreno, M., & Lessard, C. (2004).Concept of the nature of science (NOS) of a group of teachers in an immersion program of teacher-training in science. *Revista Electrónica de Investigación Educativa*, *6* (2). Retrieved month day, year, from: http://redie.ens.uabc.mx/vol6no2/contents-barona.html

ISSN: 1607-4041

Revista Electrónica de Investigación Educativa

Vol. 6, No. 2, 2004

Concept of the Nature of Science (NOS) of a Group of Teachers in an Immersion Program of Teacher-training in Science

La concepción de la naturaleza de la ciencia (NOS) de un grupo de docentes inmersos en un programa de formación profesional en ciencias

César Barona Ríos
cebar63@yahoo.com.mx
Facultad de Psicología
Universidad Autónoma del Estado de Morelos

Av. Universidad 1001
Col. Chamilpa, 62210
Cuernavaca, Morelos, México

Janet Paul de Verjovsky
janet_verjovsky@yahoo.com
Departamento de Investigaciones Educativas
Centro de Investigación y de Estudios Avanzados
Instituto Politécnico Nacional

Calzada Tenorios 235
Col. Granjas Coapa, 14330
México, D. F., México

Marcela Moreno Ruiz
jossru@hotmail.com
Escuela de Enfermería
Universidad Autónoma del Estado de Morelos

Calle Pico de Orizaba No. 2
Col. Los Volcanes, 62350
Cuernavaca, Morelos, México.

Claude Lessard
claude.lessard@umontreal.ca
LABRIPROF-CRIFPE
Faculté des sciences de l'éducation
Université de Montréal

6128 Succursale Centre Ville H3C 3J7
Montreal, Quebec, Canadá

(Received: November 14, 2003; accepted for publishing: June 14, 2004)

Abstract

This paper shows how a group of science teachers immersed in a training program—a Master's Degree in Science Education (MSE) in a Mexican public state university—modified their initial profiles concerning the concept of the nature of science (NOS). The empirical information, collected at different times during the two years of the MSE, comes from a single group of 11 teachers, who taught scientific subjects, by and large, in high school. The results in this first portion of the research project, show that the MSE improves the group of teachers' initial inconsistent profies, as the pattern of the group shifted toward relativism. The difficulties of reducing the NOS to a technical model of content organization are discussed. Also approached is a line of interpretation concerning the teachers' scientific literacy.

Keywords: Concept of the nature of science, teacher training, change of perception.

Resumen

Este trabajo muestra cómo un grupo de docentes del área de ciencias inmersos en un programa de formación —la Maestría en Enseñanza de las Ciencias (MEC) de una universidad estatal mexicana— modificaron sus perfiles iniciales acerca de la concepción de la naturaleza de la ciencia (CNC). La información empírica, recogida en diferentes momentos de los dos años de duración de la MEC, proviene de un grupo único de 11 docentes, quienes enseñan materias científicas, principalmente, en escuelas de educación media superior. Los resultados en este primer recorte de investigación, muestran que la MEC mejora los perfiles iniciales incoherentes de la CNC del grupo de docentes, al adoptar un patrón de grupo que tiende hacia el relativismo. Se discuten las dificultades de reducir la CNC a un modelo técnico de la organización del contenido. Se

aborda también una línea de interpretación que se refiere a la alfabetización científica de los docentes.

Palabras clave: Concepción de la naturaleza de la ciencia, formación del profesorado, cambio de percepción.

Introduction

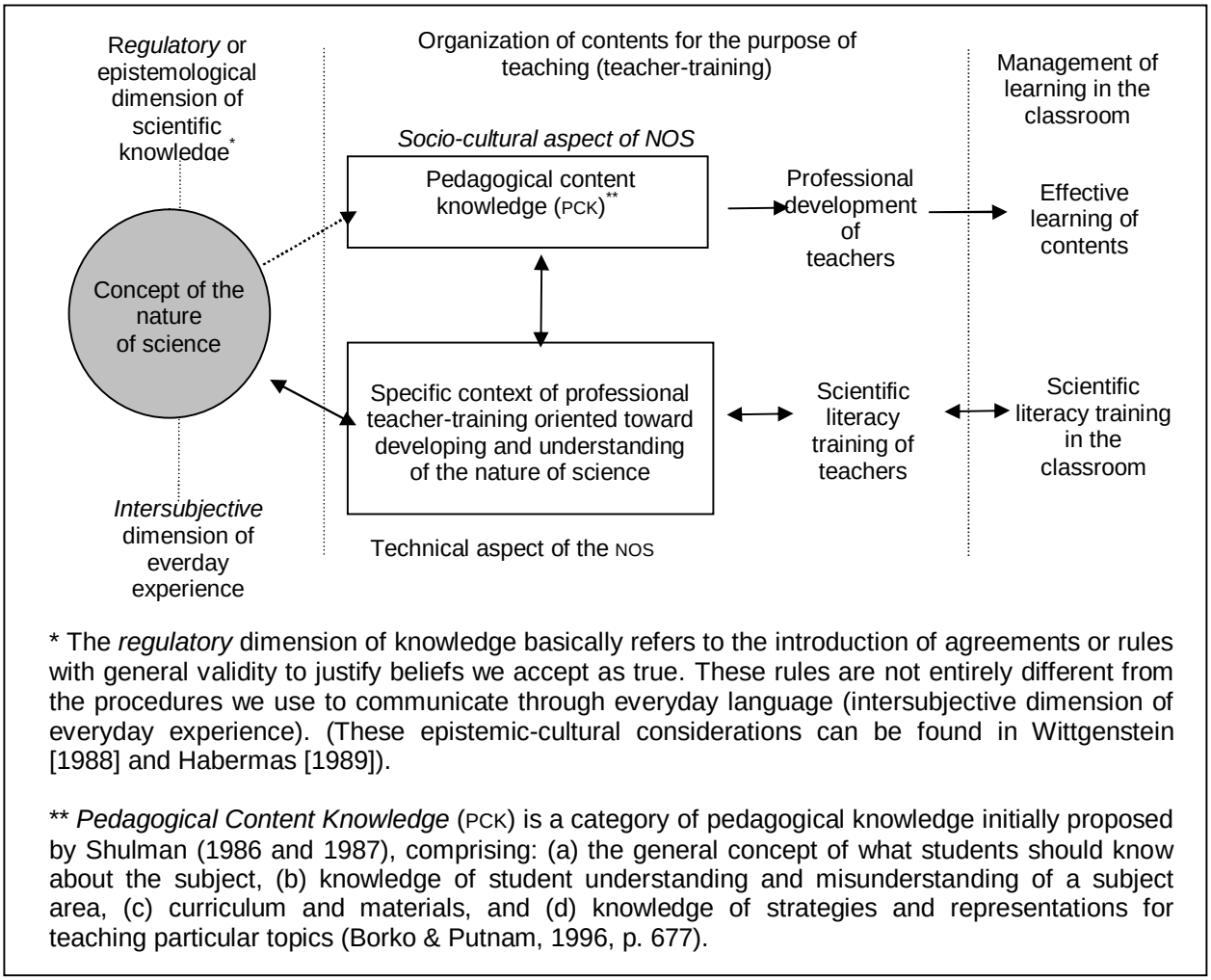
Recent research highlights the limited impact of the courses periodically organized by educational institutions for the training of their teachers. Once the courses are over, teachers resume their old practices.[1] Some Mexican universities have opened teacher-training programs with better coordination; for example, the Master's Degree in Science Education at the Autonomous University of Nuevo Leon (Mexico), a program also given at the Autonomous University of Morelos (Mexico), the institution at which the training experience with which we are concerned took place.

The initial problem we faced was the lack of information with which to assess the impact of teacher-training programs that have surpassed the isolated courses, and have been able to coordinate the pedagogical training and disciplinary preparation in a master's degree program. This situation is our object of research, but viewed from an alternative position, which goes beyond the objectivist criteria of the accumulation of the rules and procedures of the scientific disciplines.

Among the alternatives to this disciplinary objectivism, the one that stands out is constructivism, a trend linked to the studies of Piaget, and which recognizes the student's learning as the foundation for the internalization of teaching content. Recently, the teachers' learning (for example, the study of beliefs) has also drawn attention as a research object. One aspect of its study is the concept of the nature of science (NOS). However, constructivist research for studying teacher-training, such as the NOS, is still not free from objectivism.

With some caution, we could say that most teacher-training courses for high schools, regardless of their orientation (disciplinary update, philosophy, psychopedagogy, etc.), are based on a concept of education as a problem of curriculum updating and methodologies, but avoid discussing the pedagogical and epistemological foundations.

The research objective of the stage reported here was to analyze the changes brought about in the NOS of a group of teachers involved in the MSE, to point out the difficulties of linking the NOS with the organization of content for purposes of teaching and learning, and to offer a possible means of interpretation that would mesh well with the technical exigencies of practice, without losing sight of the regulatory or epistemological dimension of the NOS (see Figure 1).



* The *regulatory* dimension of knowledge basically refers to the introduction of agreements or rules with general validity to justify beliefs we accept as true. These rules are not entirely different from the procedures we use to communicate through everyday language (intersubjective dimension of everyday experience). (These epistemic-cultural considerations can be found in Wittgenstein [1988] and Habermas [1989]).

** *Pedagogical Content Knowledge* (PCK) is a category of pedagogical knowledge initially proposed by Shulman (1986 and 1987), comprising: (a) the general concept of what students should know about the subject, (b) knowledge of student understanding and misunderstanding of a subject area, (c) curriculum and materials, and (d) knowledge of strategies and representations for teaching particular topics (Borko & Putnam, 1996, p. 677).

Figure 1. The NOS and two theoretical-methodological aspects of its study with teachers: technical perspective and socio-cultural perspective

In Mexico, since there are not many such studies, this work contributes to educational research by supplying evidence to evaluate the impact of a training program which integrates the disciplinary and pedagogical aspects, from the position of the NOS. It also contributes by pointing out that the topic of scientific literacy, inherent in the regulatory or epistemological dimension of the NOS, is not directly linked with the knowledge of content, and requires more attention in training programs for teachers in their respective areas.

In the theoretical section we present the arguments on the NOS in the line of teachers, emphasizing two possible routes of connection: one having a technical orientation, and the other, a cultural. In the methodological section we offer the criteria we have followed in exploring the NOS in the group of teachers involved in the MSE. The results section shows the changes in the NOS of the group of teachers in training, and discusses ways of interpretation mentioned in the theoretical section. In closing, we point out the implications for the professional training of teachers, and future research in the field of science education.

I. The concept of the nature of science (NOS)

In the review of Lederman (quoted in Mellado, 1998) conducted in the early nineties, there is a strikingly broad variety of studies on the NOS, several of them inspired by the paradigm of process-product research. It should be noted that this pattern prevailed in the seventies in the context of American educational research. Its basic claim was to analyze the educational process as an information system independent of the inter-subjective internalization of the subjects. This paradigm began to lose ground with the emergence of cognitive science and ethnomethodological research in the eighties, and with the development of the paradigm of teachers in the nineties (Gauthier, Desbiens, Malo, Martineau and Smardan, 1997.) In the same review Lederman recognizes two main lines of study on the NOS: one directed toward curriculum problems, and the other toward teachers. Concerning the latter, we will comment on some studies.

For purposes of exposition, we present a research group whose main interest has been the integration of the NOS into the organization of content (technical aspect). We also present other studies which approach the NOS by incorporating intersubjective factors into its categories (socio-cultural aspect). These lines of study carry with them different interpretations of the results of teachers' NOS, and important implications for their professional training.

1.1. The NOS of teachers in the technical aspect

Emma Carvajal and Rocio Gómez (2002) analyzed the concepts of science and learning of junior high and high school teachers in Mexico. They interviewed seven teachers selected from a larger sample of 66 subjects. The authors concluded that the seven teachers reflect little about the cultural, ethical and philosophical aspects of science. Furthermore, there seems to be no consistent relationship with the concept of learning. In their recommendations, the authors advocate confronting ideas about the nature of science.

Angel López, Fernando Flores and Leticia Gallegos (2000) analyzed the concepts of science and learning of a group of 12 teachers of the *Colegio de Bachilleres*[2] immersed in the specialty in Physics Education. They determined the concepts of science and learning through structured questionnaires, and concluded that teachers show a change, in passing from traditional scientific conceptions concepts to constructivism, although this is less evident in the area of learning, particularly

when associated with classroom situations. The authors distinguish two categories of teachers' concepts: that of science and that of learning, and two dimensions of integration: theory and practice.

Abd-El-Khalick and BouJaoude (1997) made a distinction between high and low scientific literacy. They explored the profiles of junior high school teachers in Physics, Chemistry and Biology, and obtained the profiles of the NOS after administering a part of the questionnaire *Views of Science-Technology-Society* (VOSTS) designed by Aikenhead (1992). The profiles are attached, on the one hand, to a variable pattern of the NOS; on the other, they are not related to meaningful learning situations in everyday life.

Tobin and Campbell (1997) also reported a variable pattern of the NOS of a Chemistry teacher, which they determined by means of a questionnaire. However, when they explored this through narration by the teacher and students in the classroom scene, they found that the concept of both was similar; both the teacher and the students assumed the content of the Chemistry course to be an activity oriented toward the learning of definitions, which reveals, ultimately, a shared traditional pattern of teaching and learning.

As for Mellado (1998), he found that the concepts of the nature of science held by the group of teachers with whom he conducted his research presented variable positions having no apparent relation to the behavior described by qualitative procedures (questionnaires, interviews and triangulation of information with teachers), in classroom learning sequences. The teacher with the most "positivist" concept in the study was, as well, the most "constructivist" in learning. The teacher with the most "relativistic" concept followed a traditional, transmissive teaching model (Mellado, 1998, p. 1103).

As we can see, the first three groups of authors described the NOS as passive knowledge through structured interviews and questionnaires, which makes it difficult to establish a relationship between a propositional concept (the manifest) and its "incarnation" in classroom practice (the latent). However, Tobin and Campbell (1997) as Mellado (1998), reviewed the implementation NOS as practiced in the classroom, and showed the advantage of using qualitative procedures, above all, of a narrative type, to specify the NOS in practice.

Most of these authors recognize that it is important to work on the NOS during the teachers' training because it improves their understanding of science. In spite of that, whether the NOS should be considered within the axis of the theory or that of the practice. This is because, among other things, the practice of teacher-training is understood as an activity of individual learning and as an objectivist attempt to reduce the regulatory principles of the agreement (foundation of the epistemology) to explanatory processes.

1.2. The NOS of teachers in the socio-cultural current

Recently, there have been published new studies that help to explain why, in spite of the promotion of constructivist methodologies for improving competence in knowing the content, and the introduction of technological innovations, teaching—that is, teachers' practice—reproduces what Smolicz and Nunan (in Cobern, 2000, p. 233) call the *myth of the school of science*, i.e. a scientific vision characterized by classical realism, philosophical materialism, strict objectivity, and the hypothetical-deductive method.

The authors cited in the previous section bring up the issue of dissociation between theory and practice: the teachers say one thing, and do quite another (López, Flores and Gallegos, 2000). Some of them also recognize a dissociation between *passive knowledge* and *dynamic knowledge* (Mellado, 1998).

In our opinion the problem of persistent traditionalism goes beyond the technical framework, because there is a possibility that a greater competence in the knowledge of the content (a generic way to refer to *pedagogical knowledge of the content*) does not translate into a better understanding of *the nature of science.* The reason is that this would imply recognizing the regulatory dimension of the agreements on the structure of content knowledge. The difficulty in going back has pushed aside a need to review the rationality of the models of the technical current in science education, allowing the exposition of the NOS's cultural current.

For the cultural focus, the purpose of the NOS is to consider the intrinsic science-culture (social) relationship, and that of knowledge-beliefs (individual). The theory-practice relationship is established as a communicative competency, hence the importance attached to *scientific literacy* (including the information and communication technologies).[3] The strength of the cultural perspective—in our opinion—is that from the beginning it introduces the intersubjective dimension as part of the structure of knowledge, and avoids having to justify the epistemological problem of the separation between theory and practice.

For the sociocultural current of the NOS, the knowledge of science content is constructed within certain social, historical and cultural boundaries *(relativism)*, distancing itself from the *modernism* of science prevalent in the nineteenth and mid-twentieth century (Mathews, 1998; Cobern, 1993; Arnay, 1997, Taylor 1998). According to this current, the NOS is a fertile field that combines aspects of social studies, such as history, sociology and the philosophy of science, with research on cognitive science—psychology, for examplein a rich description of science, of the way how scientists work and operate as a social group, and how society itself directs and reacts to scientific endeavors (McComas, Clough and Almazroa, 2000, p. 4).

One reason to reevaluate the topic of the NOS is that while knowledge of the content of science, i.e. scientific knowledge organized for teaching and learning purposes, may not be necessary for improving science *literacy*—the

understanding of the nature of science—it is a prerequisite for such literacy (Shamos cited in McComas *et al*., 2000, p. 9). In the case of teachers, it has been documented that the presentation of content with reference to the NOS, measured at the beginning and at the end of training with different instruments (among them, the Wisconsin Inventory of Science Processes [WISP] and the Nature of Science Test [NOST]), show a positive correlation (McComas *et al*., 2000, pp. 27-28). Figure 1 summarizes the location of the NOS and the two theoretical and methodological ways that guide us in evaluating the changes in a group of teachers' NOS.

II. Methodology

2.1. The Master's Degree in Science Education (MSE)

Between 1999 and 2001 there was implemented in Mexico's Autonomous University of the State of Morelos (UAEMOR), an in-service program for the training of high school teachers: the Master's Degree in Science Education (MEC). The program was promoted as part of reforming the school curriculum of the UAEMOR, which was launched for reasons including low levels of high-school students' achievement, particularly in science, revealed in the results of the tests applied by the University (UAEMOR, 1996).

The MEC was mainly directed toward teachers in the field of science (Physics, Chemistry and Biology), and who were teaching those subjects. The program was coordinated by an academic unit (Mathematics Education Unit at the Institute of Education), in which teachers in the fields of science and of education came together. It was an attempt to link training in the discipline with pedagogical preparation. With some modifications, it was implemented in keeping with the model of the Autonomous University of Nuevo León.

The master's degree program was designed to run for eight quarters, with a block of common subjects (Theories of Learning, and Intellectual and Personality Development; General Education; Evaluation; Projects Development in Science Teaching), an elective from a group of three (Science and Society in the Twentieth Century, Education and Human Resources in Industrial Societies, or Cognitive Psychology) and a research seminar. The MEC has three specific curriculum blocks: Biology, Physics and Chemistry.

The course in the epistemology issue was introduced in the Project Development Seminar, in the introductory module called *Science, Method and Scientific Change*. Approximately 10 hours of the 40-hour seminar were devoted to it, with these topics covered: *Methodology in Science, The Structure of Scientific Revolutions (Thomas S. Kuhn), Research Programs (Imre Lakatos), The Continuity of Research (Stephen Toulmin), The epistemological concept of Karl Popper* and *The epistemological Concept of David Hull.* The foundational reading was *Methodology in Science. Epistemology and Darwinism* by Rosaura Ruíz and Francisco J. Ayala, published in 1998 in Mexico by the Fund for Cultural Economics.

2.2. The MEC Teachers and their teacher-peers

The MEC group was composed of 11 in-service teachers, nine from high schools, and two who were university undergraduates. Of the total number, 5 taught Biology, 5 taught Chemistry, and one taught Physics. There were seven women and 4 men, all between 34 and 59 years of age. Two teachers were biologists, three were chemical engineers, three were normal-school teachers (one taught biology and two taught physics and chemistry); there were an industrial chemist, a dental surgeon and a general surgeon. The teachers had from 6 to 33 years of experience. Only one taught fulltime, and the others had part-time teaching positions.

The group of peers from outside the MEC was made up of 12 teachers invited by those enrolled in the Master's Degree program, with the condition that they must be persons who worked in the same institution. Other than that, no individual information about them was collected.

2.3. Strategy for analysis, and instrument for data collection

The study on the training experience of a group of teachers came after the MEC was formed. This helped solve the problem of sampling, but the problem of the observations' validity persisted. A group of 11 teachers is not representative of a population of some 500 senior high school teachers at the university where the study was conducted. For this reason we chose the *qualitative* approach to the *case study*, which is defined as *"the study of the example in action"* (Walker quoted in Mellado, 1998, p. 1098). For Shulman (quoted in Montero, 2001), the case study refers to learning from experience: as seeing how other teachers teach, going beyond the axis of theory and practice.[4] Our example is a group of teachers in training, and constitutes the basis of general information about the project; however, it was necessary to make cuts. Each cut required different instruments. For this article we confined ourselves to analyzing the NOS (see Figure 2) through the use of a structured questionnaire.

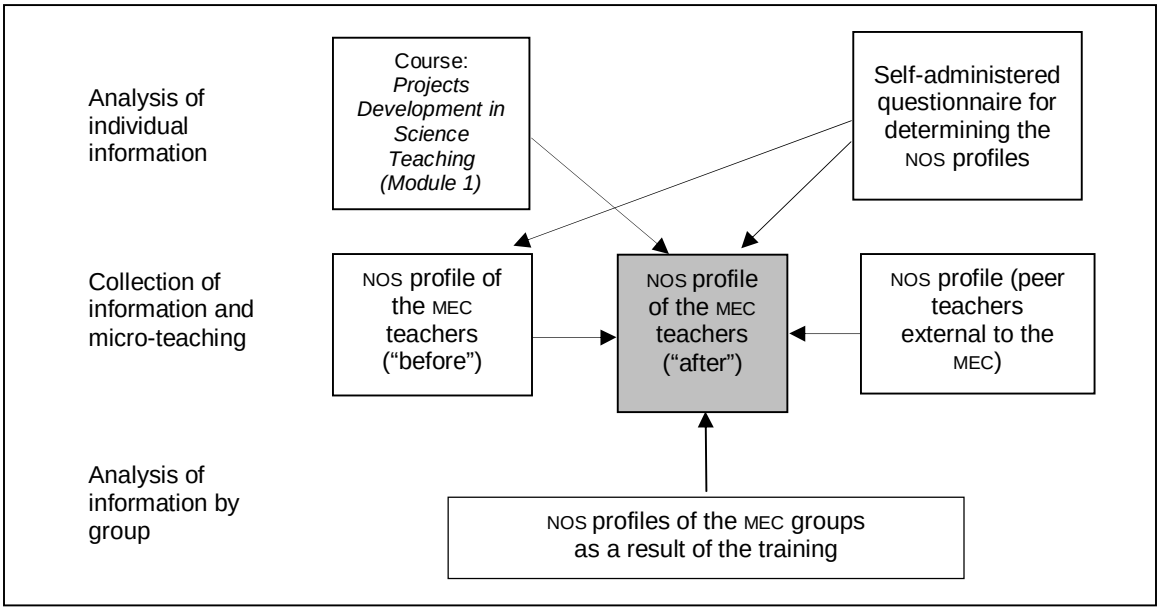


Figure 2. Schematic for exploring the concept of the nature of science (NOS) in teachers in training, in two moments (*before* and *after*), and in peer teachers external to the MEC by means of a self-administered questionnaire

The information was obtained at the initial stage of the MEC (in 2000), and after the module was taught with epistemological information (mid-2001). To determine the profile of the nature of science, the data were collected through a self-administered questionnaire, the design of which was taken from Nott and Wellington (cited in Monk and Dillon, 1996). This instrument consisted of 24 statements and an attitude scale with values ranging from -5 (strongly disagree), 0 (neutral) and +5 (strongly agree). Nott and Wellington (2000) suggest that although the profiles are presented in scales, the intention is to encourage self-reflection on the positions by teachers in the context of training. For us this means training in the MEC program, the dialogue with teachers in the seminar and its expression in the NOS. To link the teachers' profiles with scenes of classroom practice, the authors designed a complementary method of *critical incidents* and *exemplifications* of the NOS in the classroom. However, these two aspects were not part of the objective of our investigation.

The values of the statements were placed in a table with 5 axes that correspond to epistemological positions extracted from several intellectual traditions of history, philosophy and the sociology of science: relativism/positivism (R/P), inductivism/deductivism (I/D), contextualism/decontextualismo (C/D), propeled by the process/propelled by the content (P/C), instrumentalism/realism (I/R). The questionnaire also provides definitions of the epistemological positions (see Annex 1). In this work we present a re-interpretation of data analyzed in two previous works (Barona and Verjovsky, 2001, Barona, Verjovsky and Lessard, 2003), but explored more deeply, and with other elements of analysis.

III. Results and discussion

What is the NOS of teachers during training in the context of the MEC? In the first self-administration of the questionnaire, when new teachers had just entered the master's degree program, no positional pattern was observed. The group's profiles were typified by a lack of reflection on the NOS.

A year later, we applied the questionnaire for a second time, taking advantage of the fact that the teachers were finishing the Project Development Seminar, the first module of which provided epistemological information. Thus, we could compare the profiles twice (*before* and *after* receiving epistemological information).

The results of the second application of the survey show that the profile of six teachers (54.5%) corresponds to a variable pattern of the NOS. In four cases (36%) profiles of teachers are consistent, or show an improved level of consistency, as compared with the first time they took the survey. In 63% of teachers there was recognized a shift toward *relativism* in the pattern of profiles (Table I).

Table I. The NOS of teachers in service *before* and *after* receiving epistemological information

Teacher	**First self-administration (without training in scientific theory)**	**Second self-administration (with epistemological information)**	**Individual NOS profile**
1	Inductivism	Decontextualism	Variable pattern
2	Contextualism Relativism	Relativism	Defined consistency
3	Process	Relativism	Variable pattern
4	Positivism	Relativism	Improved consistency
5	Relativism	Relativism	Confirmed consistency
6	Instrumentalism	Process	Variable pattern
7	Relativism	Process	Variable pattern
8	Contextualism	Instrumentalism Relativism	Variable pattern
9	Process Relativism	Process	Consistency
10	Contextualism	Relativism	Variable pattern
11	Did not apply	Relativism	
Group nos profile	No group pattern recognized	Group pattern shifted toward relativism	

As a result of the philosophical education received in the second administration of the questionnaire to determine the NOS, it was observed that in some cases the consistency was changed, and in general, the training contributed to the formation of a pattern of positions. After receiving the epistemological information, most teachers in the MEC group became affixed to *relativism.* In the field of science education this can be considered as a kind of *constructivism.* This change is consistent with the results López, Flores and Gallegos (2000) reported for the science concepts of a group of teachers from the *Colegio de Bachilleres* in Mexico City; the results were determined with structured questionnaires.

To contrast the MEC milieu with the environment which had no intervention, we asked each teacher enrolled in the program to give the questionnaire to a teacher/peer not enrolled in the program, and preferably working at the same place. The results of the teachers outside the MEC are similar to the first self-administration of the MEC teachers; no consistent pattern of positions is recognized. Of the profiles of the 12 outside teachers, five are positioned in decontextualism, 3 in the process position, 3 are relativist, and 1 is an inductivist.

The change of epistemological positions of the MEC group, contrasted with the first self-administration of the questionnaire and the data from the peer group of teachers, suggests that a university education does have an influence. The positions shift toward constructivism, which indicates that epistemological information helps to clarify the poverty of concepts in the group's initial conditions and in their normal workplaces conditions, detected through the profiles of the teachers from outside the MEC.

For studies of the technical side, the NOS is an important factor in the teachers' culture, but not necessarily for learning the teaching content. This consideration is found in the work of Abd-El-Khalick and BouJaoude (1997); it is also noted in the analytical framework of the study of Carvajal and Gómez (2002). However, the NOS is subordinated to the integration of the knowledge of content and learning effectiveness.

If the expected relationship is located exclusively on the axis that goes from theory to practice, or vice versa, important measurements are lost. The relationships in science and education, because of the socio-cultural line, can also be expressed as certain forms of representation. The change of the initial NOS profiles to a pattern with a certain consistency, more than a theoretical transformation, is in a way, a step from one way of understanding certain propositions to another way of understanding these same propositions. Teachers learn to express their ideas better when they have the opportunity to read and discuss with colleagues the meaning of what is asked on a questionnaire. The NOS profile is not directly related to the development of content knowledge, but to scientific literacy. In our opinion, the basic sense of scientific literacy is to understand the meaning of a language in a given context of use.

IV. Implications for teacher-training, and research prospectus

The evidence gathered from what occurred with the teachers' internalization of the knowledge they gained from the MEC experience, the documented experiences in teacher-training (such as that in the *Colegio de Bachilleres*), and the ample bibliography in the international environment permits us to see that the training programs better articulated and associated with formal postgraduate programs, positively modify the teachers' initial conceps.

A review of the literature in the field of science education, corroborated by empirical information on training within the MEC, indicates that the program modifies the NOS, a change that suggests a certain communicative competency that gives meaning to what is asked on a questionnaire, in a specific context of training in microteaching. This aspect may be buttressed in an *ad hoc* seminar connected with teacher-training. We explored the NOS in two stages, and only with a microteaching module that provided an overview of the epistemology of a project-design seminar.

Due to the limits of our research goal, we tabled the followup of the NOS in the setting of daily practice through qualitative methods. Teachers with a new, consistent position may improve the *scientific literacy* of their students; although this would need to be explored specifically in order to confirm it, as related with the comprehension of certain propositions a propos the language of science and the sense of its use, with paradigmatic examples in touch with the experiences of everyday life. Or, explore other ways of contextualizing the internalization of science as a culture This is part of the future research agenda.

This first cut of the study also requires an analysis of the knowledge of the content, specifically knowledge of the subject. Figure 1 indicated an indissoluble relationship between *scientific literacy* and *pedagogical content knowledge* (PCK), although the improvement of content knowledge is not a prerequisite for *literacy,* it is indeed a prerequisite for a better understanding of the nature of science. Nor would it make sense to understand this nature without understanding the rules of the content that must be taught. We have left this aspect open for the next study.

Another aspect to be addressed in the future is the analysis of institutional factors in the training of science teachers. We believe that several obstacles not discussed in this paper have little relation to the deficiencies in teachers' knowledge, and everything to do with the "politics of perceptions" of knowledge (term from Donmoyer, 1996). It is inconsistent for teachers to develop a specific knowledge in certain areas of collegiate interaction, while the institutional regulation of university professionalization (as pointed out by Lessard and Bourdoncle, 2002) is concentrated precisely on factors—such as the professionalization of research—that lead to the fragmentation of teachers' work and especially, the work of high school teachers.

References

Abd-El-Khalick, F. & BouJaoude, S. (1997). An exploratory study of the knowledge for science teaching. *Journal of Research in Science Teaching, 34* (7), 673-699.

Aikenhead, S. G. & Ryan, G. A. (1992). The development of a new instrument: "Views on science-technology-society" (VOSTS). *Science Education, 76* (5), 477-791.

Arnay, J. (1997). Reflexiones para un debate sobre la construcción del conocimiento en la escuela: hacia una cultura científica escolar. In M. J. Rodrigo & J. Arnay (Comps.), *La construcción del conocimiento escolar* (pp.35-58). Barcelona: Paidós.

Barona, C. & Verjovsky, J. (November, 2001). Las concepciones de la naturaleza de la ciencia de los profesores de las preparatorias de la UAEMor. *Memoria del VI Congreso Nacional de Investigación Educativa* [Compact disc]. Mexico: Consejo Mexicano de Investigación Educativa-Universidad de Colima.

Barona, C., Verjovsky, J., & Lessard, C. (August, 2003). Conceptions of the nature of science of Mexican high school science teachers. Paper presented at *10th Biennial Conference of Earli*, Padova, Italy.

Borko, H. & Putnam, R. (1996). Learning to teach. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp.673-708). New York: Macmillan.

Carvajal, E. & Gómez, R. (2002). Concepciones y representaciones de los maestros de secundaria y bachillerato sobre la naturaleza, el aprendizaje y la enseñanza de las ciencias. *Revista Mexicana de Investigación Educativa, 7* (16), 577-602.

Cobern, W. (1993). Contextual constructivism: The impact of culture on the learning and teaching of science. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 51-69). Hillsdale, NJ: Lawrence Erlbaum.

Cobern, W. (2000). The nature of science and the role of knowledge and belief. *Science and Education, 9* (3), 219-246.

Cole, M. & Keyssar, H. (1985). The concept of literacy in print and film. In D. R. Olson, N. Torrance, & A. Hildyard (Eds), *Literacy, language, and learning. The nature and consequences of reading and writing*. Cambridge: Cambridge University Press.

Donmoyer, R. (1996). The concept of a knowledge base. In B. F. Murray (Ed.), *The teacher educator's handbook. Building a knowledge base for the preparation of teachers* (pp. 92-119). San Francisco: Jossey-Bass.

Gauthier, C., Desbiens, J.-F., Malo, A., Martineau, S., & Simard, D. (1997). *Pour une théorie de la pédagogie. Recherches contemporaines sur le savoir des enseignants*. Sainte-Foy, Canada: Les presses de l´Université Laval.

Habermas, J. (1989). *Teoría de la acción comunicativa. Complementos y estudios previos.* Madrid: Editorial Cátedra.

Lessard, C. & Bourdoncle, R. (April-June, 2002). Qu'est-ce qu'une formation professionnelle universitaire? Conceptions de l'université et formation professionnelle. *Revue française de pédagogie, 139*, 131-154.

López, Á., Flores, F., & Gallegos, L. (2000). La formación de docentes en física para el bachillerato. Reporte y reflexión sobre un caso. *Revista Mexicana de Investigación Educativa, 5* (9), 113-135.

Mathews, M. (1998). The nature of science and science teaching. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (Vol. 2, pp. 981-999). London: Kluwer Academic Publishers.

McComas, W., Clough, M., & Almazroa, H. (2000). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education. Rationales and strategies* (pp. 3-39). Dordrecht, Netherlands: Kluwer Academic Publishers.

Mellado, V. (1998). Preservice teachers' classroom practice and their conceptions of the nature of science. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (Vol. 2, pp. 1093-1110). London: Kluwer Academic Publishers.

Monk, K & Dillon, J. (1996). *Learning to teach science: Activities for student teachers and mentors*. London: The Falmers Press.

Montero, L. (2001). *La construcción del conocimiento profesional docente*. Rosario, Argentina: Homo Sapiens Ediciones.

Nott, M. & Wellington, J. (2000). A programme for developing understanding of the nature of science in teacher education. In W. F. McComas (Ed.). *The nature of science in science education. Rationales and strategies* (pp. 293-313). Dordrecht, Netherlands: Kluwer Academic Publishers.

Universidad Autónoma del Estado de Morelos (1996). *Reestructuración del plan de estudios de nivel medio superior (Proyecto de Reforma Académica del Bachillerato)*. Mexico: Universidad Autónoma del Estado de Morelos-Secretaría de Rectoría.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15* (2), 4-14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57* (1), 1-22.

Taylor, P. (1998). Constructivism: Value added. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (Vol. 2, pp. 1111-1123). London: Kluwer Academic Publishers.

Tobin, K. & Campbell, M. (1997). Beliefs about the Nature of Science and the Enacted Science Curriculum. *Science & Education, 6*, 355-371.

Wittgenstein, L. (1988). *Investigaciones filosóficas.* Barcelona: Editorial Crítica.

Annex I

Definitions of the axes of Nott y Wellington's questionnaire (2000, pp. 312-313) for determining the profile of the *concept of the nature of science* [Free translation by the authors][*]

1. Relativism/positivism

Relativistic: You deny that things are true or false if you base your thinking only on an independent reality. The "truth" of a theory depends on the rules and rationality of a social group considered, as well as the experimental techniques used to evaluate it. The perceptions and truth of scientific theories vary from one individual to another and from one culture to another. Example: truth is relative, not absolute.

Positivist: You really believe that scientific knowledge is more "valid" than other forms of knowledge. The laws and theories generated by experiments are the descriptions of the patterns we see in a real, objective, external world. For the positivist, science is the primary source of truth. The positivist recognizes empirical facts and observable phenomena as the raw material of science. The work of the scientifist is to establish objective relationships between the laws that govern facts, and what can be observed. The positivist rejects examining root causes and fundamental origins.

2. Inductivism/deductivism

Inductivist: You believe that the work of the scientist is the interrogation of Nature. Through observation of particular cases, one can infer `from the particular, and then determine the basic laws and theories. According to Inductivism, scientists generalize *inductively* from a set of observations to reach a universal law. Scientific knowledge is built by induction based on a sure group of observations.

Deductivist: In our definition this means that you believe that scientists proceed by means of the evaluation of ideas produced by a logical sequence of everyday theories, or of their bold and imaginative ideas. According to deductivism (or hypothetical-deductive reasoning), the scientist's reasoning consists of the formation of hypotheses not established by empirical data, but suggested by them. Science, therefore, proceeds to evaluate the observable consequences of those hypotheses; for example, the observations are directed or headed by hypotheses—they are loaded theories.

[*] Note from the translator of the English version of this article: The text cited, originally written in English, was freely translated into Spanish by the authors of this study for use in their Spanish-language work. As the original text was unavailable to the translator of the English version, it was necessary to employ the technique of back-translation, for which we offer our most humble apologies.

3. Contextualism/decontextualismo

Contextualism: You hold the view that the truth of scientific knowledge and processes is interdependent with the culture in which scientists live, and in which their work is carried out.

Descontextualismo: You hold the view that scientific knowledge is independent of its cultural location and its sociological structure.

4. Process/Content

Process: You see science as a distinct collection of identifiable methods/processes. Learning is an essential part of education in science.

Content: You think science is characterized by facts and ideas that it has, and that the essential part of science education is the acquisition and management of "this body of knowledge."

5. Instrumentalism/realism

Instrumentalism: You believe that scientific theories and ideas are good while they work, that is, they allow correct predictions to be made. These are tools we can use, but they tell us nothing about independent reality or truth itself.

Realism: You believe that scientific theories are statements about a world that exists in a space and time independent of scientists' perceptions. Correct theories describe things that actually exist in a manner independent of the scientists—for example, atoms and electrons.

Translator: Lessie Evona York-Weatherman

UABC Mexicali

---

[1] Some experiences in training high school teachers in the area of science show that the courses they take have little effect in the classroom. As soon as the teachers finish the courses, they go right back to the traditional ways of teaching (López, Flores and Gallegos, 2000).

[2] *The Colegio de Bachilleres* (School of Bachelors) is a decentralized organization of the Mexican State, created by presidential decree September 26, 1973. It offers high school studies at a national level, in both presencial and open modalities (To read more about it, see http://www.cbachilleres.edu.mx/).

[3] *Literacy* can be translated as "basic reading and writing"; but the English word is broader in meaning: "*Literacy* is conventionally understood as the ability to use graphic symbols to represent a spoken language. *Literacy* thus conceived is an important type of mediated human activity. One form of *literacy* is printed matter. Furthermore, in ordinary language, *literacy* often means the ability to interpret or negotiate understanding within some means of communication" (Cole and Keyssar, 1985, p. 50) [Free translation and emphasis by the authors]. Abd-El-Khalick y BouJaoude (1997, p. 673) understand *scientific literacy* in this way: "In very general terms, a person literate in science can develop and understand the concepts, principles, theories and processses of science, and a consciousness of the complex relationships between science, technology and society. More importantly, such a person will develp an understanding of the nature of science" [Free translation by the authors].

> Note from the translator of the English version of this article: According to the above endnote, the texts cited, originally written in English, were freely translated into Spanish by the authors of this study for use in the Spanish-language text. As the original works were unavailable to the translator of the English version, it was necessary to employ the technique of back-translation, for which we offer our most humble apologies.

4 The study of the case in education goes beyond the parameters of the relationship between theory and practice. As Shulman points out: "It is not necessary for every teacher to learn about practice through his or her direct experience only. As Bruner observed concerning learning through discovery, it would be absurd for every generation to have to discover what has already been discovered by our predecessors. Practice can be learned from vicarious participation in others' experience, adequately documented, distributed and discussed. This is where the role of the cases comes to be central in the dissemination of new examples (...) Teachers can read about cases that register the experiences of other teachers (...) In this direction the improvement of teaching can be obtained by moving from one teacher's practice to another teacher's practice, and not exclusively from theory to practice, or from practice to theory (Shulman, cited in Montero, 2001, p. 219).