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Evolution of the conceptions of a secondary education biology teacher: Longitudinal analysis using cognitive maps

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ABSTRACT: We describe a longitudinal study of a secondary education biology teacher at two moments in her career (1993-2002), determining the changes in her conceptions of the nature of science and its teaching and learning, and the factors that favoured or hindered such changes. The changes were analyzed using cognitive maps constructed on the basis of the INPECIP questionnaire, designed and validated by Porlán et al. (1997), and a semistructured interview.

The results showed the process of change in conceptions to be complex and gradual, with different conceptions being out of phase with each other. During her first four years of teaching, until 1993, her conceptions of science teaching and learning began to evolve from a teacher and content centred model to one that was more student centred. The catalyst of the change in her initial conceptions of teaching and learning was her becoming aware of the students' alternative ideas.

Her empiricist conception of the nature of science, however, remained practically unaltered during these first four years. This conception began to shift slowly towards less dogmatic and more up-to-date positions as a consequence of her changing view of teaching-learning, and by 2002 there was again coherence between her scientific thinking and her ideas on science teaching and learning.

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INTRODUCTION

Understanding the factors that favour or hinder the processes of educational change in teachers has become one of the principal themes on the agenda of educational research (Davis, 2003; Hargreaves et al., 1999; Mellado et al., 2006), and is an essential element in the planning and practice of teacher education and professional development programs (Abell & Pizzini, 1992).

While structural and curricular changes in education are necessary, they may not be sufficient unless they take into account that the teacher is the key to qualitative improvement of education systems, and determines the success or failure of whatever curricular reform or innovation it is desired to implement (Fullan, 1991; Tobin, Tippins & Gallard, 1994). Furthermore, structural and curricular changes by themselves are not enough to provoke educational change amongst teachers that will lead to improved teaching. The reason is that teachers are not just mere technicians limited to applying curricular reforms, but reflexive subjects whose judgements and decisions are influenced by their knowledge,
conceptions, attitudes, context, and personal antecedents (Freitas, Jiménez & Mellado, 2004; Marcelo, 1994). Teachers do not easily change their conceptions, and even less so their educational practices.

**Science teachers’ conceptions**

From a constructivist perspective, science teachers are regarded as having conceptions about the nature of science, about scientific concepts, and about how to learn and teach them (Gil-Pérez, 1993; Hewson & Hewson, 1989). These are usually deeply rooted conceptions, and a teacher's first step in his or her education and professional development is to reflect on these conceptions critically and analytically (Hewson et al., 1999b).

With respect to the nature of science, many studies concur in the need for secondary education science teachers to reflect on what scientific knowledge means. There are still, however, many impediments to this process (Matthews, 2004), and the philosophy of science is hardly touched on in teacher education. The lack of reflection on these topics is a factor contributing to the doubts and vagueness about the topic that many teachers show, and to the somewhat naive conceptions that they have about essential aspects of the nature of science, including frequent empiricist and inductivist features (Solís & Porlán, 2003; Windschitl, 2004). These empiricist features may at times coexist with other eclectic points of view about the nature of science (Acevedo, 2000; Lakin & Wellington, 1994; Manassero & Vázquez, 2000; Mellado, 1997; Verjovsky & Waldegg, 2005).

Prospective and beginning science teachers have conceptions about learning and teaching sciences, which are the fruit of the many years they themselves have spent in school and university, accepting or rejecting the roles of their own science teachers (Hewson & Hewson, 1989). Most of the novice teachers analyzed by Simmons et al. (1999) considered that the best form in which their students can learn sciences is the same as they themselves used when they were at school. Several studies have shown that these conceptions are usually closer to more teacher- and content-centred transmissive models of teaching than to models centred on student learning (García & Martínez, 2001; Gunstone et al., 1993; Solís & Porlán, 2003). Other work with teachers who hold transmissive conceptions has also found that there are teachers with more student-centred conceptions who regard learning as a change in knowledge (Aguirre et al., 1990). Nonetheless, although many of the secondary education science teachers in initial teacher education analyzed by Martínez et al. (2001) agree with the need to bear the students' previous ideas in mind, they do not consider that these ideas might be a source of professional knowledge for the teacher. A characteristic feature of novice and prospective teachers is that they usually present many contradictions: they may have teacher-centred conceptions, but perceive themselves as student-centred (Simmons et al., 1999).

Experienced science teachers have conceptions and teaching models that have been consolidated by
their own professional experience, and which are very stable and resistant to change. Sometimes this is because they feel satisfied with, and there is coherence between their goals, their conceptions, their educational practice, and their perception of the students (McRobbie & Tobin, 1995). At other times, it is because there exist conditioning elements that reinforce traditional models, and are obstacles to changing them (Shwartz, Ben-Zvi & Hofstein, 2005; Tobin, 1998; Verjovsky & Waldegg, 2005).

Teachers’ conceptions on science teaching are generally related to their conceptions on learning (Mellado, 1998). Discrepancies can arise when some of these conceptions begin to evolve to a more sophisticated form (Boulton-Lewis et al., 2001). With respect to the relationship between conceptions on the nature of science and conceptions on teaching and learning, for Brickhouse (1990) a teacher's conception of how scientific knowledge is constructed is consistent with his or her beliefs about how students learn science. Other work, however, has found discrepancies between the two (Carvajal & Gómez, 2002; Powell, 1994), and there is a greater consistency in experienced teachers than in novice or prospective teachers (Brickhouse, 1990; Dillon et al., 1994; Mellado, 1996; Tobin & Espinet, 1989).

**Educational change in science teachers’ conceptions**

Constructivist-based research on conceptual change considers that, for change to occur, it is not enough for a teacher to be dissatisfied with the old conceptions. Rather, he or she has at the same time to see the advantages in the new approaches (Gunstone et al., 1993; Hewson et al., 1999a; Stofflett, 1994).

Research with science teachers has also found that the process of teacher change is continuous but gradual (Appleton & Asoko, 1996). It is seldom a case of completely abandoning the traditional models in favour of the new, but rather one of partial acquisitions and retentions (Gunstone & Northfield, 1994). Teachers do not usually make drastic changes. Instead, they progressively put the ideas that seem to them to be important and at the same time attainable into practice. Over time, they come to regard these ideas as positive (Arora et al., 2000).

López (2000) analyzes a secondary education science teacher's process of change from a transmissive focus on teaching towards constructivist standpoints. In this process, the teacher does not completely abandon the customary traditional method of teaching based on the explanation of content, but begins gradually to take the students' ideas into account and incorporate them into new teaching strategies.

Another of the aspects that must be borne in mind is the subject being taught. According to Shulman (1986), teachers develop a body of teaching knowledge about the content, which that author termed “pedagogical content knowledge”, which is specific to each subject, is elaborated personally in the course of their teaching practice, distinguishes teaching as a profession, and is a form of reasoning and
pedagogical action by means of which they transform the content of the subject into representations that are comprehensible to their students. In novice teachers, pedagogical content knowledge develops gradually through teaching experience (Mulholland & Wallace, 2005). Indeed, its depth and scope could well serve as a major indicator of a science teacher's development from beginner to expert (Clermont, Borko & Krajcik, 1994).

Finally, we would emphasize the importance of research on metacognition in teachers. These studies consider the development of metacognitive skills to be fundamental. Such skills favour awareness of the teacher's own cognitive processes, reflection in and about action, and understanding of the causes of the difficulties in teaching behaviour and of the obstacles to educational change. They hence make self-regulation and control of the process of change possible (Baird et al., 1991; Copello & Sanmartí, 2001; Gunstone & Northfield, 1994; Gunstone et al., 1993; Lucio, 2001; Sanmartí & Jorba, 1995). Professional development has to go together with personal and social development (Bell & Gilbert, 1994), taking affective aspects into account, reinforcing the teacher's self-esteem, encouraging constructive collaboration, strengthening the culture of the corresponding school, and building on the good practice that the teachers are already carrying out (Hargreaves, 1996).

RESEARCH QUESTIONS

In sum, although one finds numerous studies that analyze the conceptions of secondary education teachers about both the nature of science and science teaching and learning, there are fewer longitudinal studies indicating how these conceptions evolve, how they are related to each other, and which are the factors in each case that favour or hinder change.

The case study that we shall describe is of Consuelo, a secondary education biology teacher. It focused on the following two research questions:

1. How have Consuelo's conceptions on the nature of science and science teaching and learning evolved from when she started out on her career as a teacher until the present?
2. What are the factors that have stimulated or hindered the evolution of her conceptions?

METHODOLOGY

The case of Consuelo

Consuelo is the first author of the present communication. She is a secondary education biology teacher with 16 years of experience teaching her subject at the secondary level, in a Concerted-Private School which is regulated and financed by the Public Administration, in a mid socio-economic zone of
Badajoz, a city of 140,000 inhabitants in SW Spain on the border with Portugal.

Consuelo is a biology graduate. In Spain, a biology graduate has a 4- or 5-year university education centred on that speciality. There is no psychopedagogy or science education since the studies are not oriented to teaching. Graduates who wish to go into secondary education teaching must take a brief postgraduate teaching course dealing with psychopedagogy and science teaching methods, and a short period of teaching practice in secondary education centres.

Consuelo began teaching in 1989 in the school in which she still teaches. In 1993, she, together with other secondary education teachers, participated in a post-graduate course given by one of the authors. During this course, she answered the INPECIP questionnaire on educational and epistemological conceptions, and the cognitive maps corresponding to her responses were drawn up by the standard procedure to be described below. In 2002, she took a course of initiation into science education research given by two of the authors, at the beginning of which she again answered the INPECIP, and the new cognitive maps corresponding to her responses were drawn up. The research group was already working on the evolution of the conceptions and practices of secondary education science teachers, and Consuelo stated her interest in doing her doctoral thesis in this line. Before working with other teachers, however, she wanted to investigate her own evolution as a teacher.

The cognitive maps from the questionnaire give a graphical picture of teachers' beliefs, but we agree with Lederman and O'Malley (1990) that questionnaires give simplified results that it is necessary to complete with other methods. Since the questionnaire is the data source for the preparation of the maps, its limitations carry over to the maps. Hence, taken by themselves, they may give an oversimplified and out-of-context view of the teacher's conceptions. Furthermore, the maps represent Consuelo's conceptions at two specific moments in her career. In order to obtain a more continuous view of how her conceptions evolved, we therefore supplemented the data with a semi-structured stimulated recall interview, and with the texts of Consuelo's reflection about the entire process. Although we only had the maps for 1993 and 2002, our intention was for the maps to be two "still photos" that would help Consuelo to reflect on and reconstruct the entire "film" of the course of her career, both during the interview and subsequently during the process of analysis.

Initially, in responding to the questionnaire in 1993 and 2002, and in the interview, her role was one of informant. She then became integrated into the research team, participating in its discussions and reflections. The study has, therefore, an autobiographical character since the participating teacher analyzes her own case with the help of the rest of the researchers. She thus plays two roles in the study — researcher, and the subject of the research. In the following, we include a reflection of Consuelo that clarifies her role as both informant and investigator:

"The experience of analyzing your own work as a teacher turns out to be highly contradictory. At first, while
listening to the interview, there arises, at least in me, an initial concern about my role as the protagonist of the interview: whether I used correct expressions, whether the tone of voice was appropriate, whether I spoke too slowly or too quickly, or whether what I said was appropriate or not. This situation made me reflect at a certain moment on how difficult it is for us teachers, in my opinion, to share our experience with other people, I do not know whether for fear of not being up to the mark professionally, or simply because our work is, on occasions, quite solitary and not always highly thought of. Also, I realize that in doing the interview I have brought to the surface thoughts that even I myself did not know that I had, and that, in effect, I am detecting what may be the causes of them. The opportunity of doing research on oneself turns out to be so interesting, then, that one can not help forgetting the initial prejudices, and suddenly you find yourself immersed in a process in which I even forget on occasions that the person I am listening to is myself. The possibilities that it offers you with regard to the future to know yourself as a teacher, being aware that you have set out on a reflexive process that has no end and that gives you an answer to many why's and that places you within a professional context, more than compensates the initial insecurity that a work of this kind causes you.” (Reflection *a posteriori*.)

We consider that there is a major educational potential in involving science teachers in research into important problems and situations of interest to them. Teachers will then be not mere consumers of external knowledge, but co-producers and agents of change in the problems that really concern them (Briscoe & Wells, 2002) There have now been numerous examples of research of this nature. Some of them have analyzed the teacher's own case, using autobiography as an element of reflection between him or her and the outside researcher (Davis, 1996; Lee & Roth, 2000; McGonigal, 2000).

**Construction of cognitive maps of teachers' conceptions on the basis of the INPECIP questionnaire**

Concept maps have been thoroughly validated in numerous studies on science teaching (Cañas et al., 2004). Their initial use was for students' learning, but there is a growing body of work that defends their use in research with science teachers (Beyerbach & Smith, 1990; Casas & Luengo, 2004; Gess-Newsome & Lederman, 1993; Powell, 1994). Applications have included determining the evolution of the conceptions of prospective science teachers about conceptual change (Markham et al., 1994) and of beginning secondary education teachers about science-technology-society instruction (Tsai, 2001), and studying the stability of pre-primary teachers' orientations (Mergendoller & Sacks, 1994).

Cognitive maps relate, in a partially hierarchized form, units of information in a wider sense than the concepts used in concept maps. The representation in a cognitive map gives an overall and unfragmented view of each teacher's conceptions about different aspects of education. Teachers may construct their own cognitive maps (Jones & Vesilind, 1995), or this may be done by an outside researcher based on data obtained from the teachers (Mellado et al., 2002).

Any questionnaire whose different categories correspond to well-defined and contraposed models can be analyzed by means of cognitive maps. In particular, Likert-type questionnaires with only two choices of response, in which the respondents express their agreement or disagreement with the statement in each item, adapt themselves to this analytical technique. The results are far better, however, when the questionnaire has been specifically drawn up bearing in mind its subsequent
analysis using cognitive maps for each respondent. We shall here describe the construction of these maps for the INPECIP (Inventory of Teachers' Pedagogical & Scientific Beliefs) questionnaire, designed in the University of Seville to determine the educational and epistemological conceptions of science teachers. The INPECIP was elaborated on the basis of interviews conducted with teachers, categorizing and drafting the propositions in the form of a questionnaire. A first validation was performed with a sample of 11 teachers (Porlán, 1989). It was subsequently used and validated in other studies involving science teachers (Porlán & Martín del Pozo, 2002, 2004; Porlán et al., 1997).

Since the INPECIP questionnaire was not specifically designed to be analyzed by cognitive maps, it can serve as an example of post-adaptation. The questionnaire consisted initially of 56 items (Appendix), distributed into four categories: personal educational model, image of science, theory of learning, and methodology of science teaching. Some modifications were made to the INPECIP for its analysis using cognitive maps (Ruiz et al., 2005). First, items 3, 12, 18, 29, and 53 were removed as not being very relevant for secondary education teachers, and hence neither for the objectives of the present study. The rest of the items were grouped into three categories: *image of science, science learning* which coincided with the questionnaire's original categories, and *science teaching* which included the original items of this category plus those initially included in the personal educational model category.

In the literature one can find different models for each category. Porlán et al. (1997) propose an evolutionary framework for teacher change: this starts from the traditional-transmissive teaching models (based on the direct transmission of information through the teacher's explanation and/or the textbook), passes through intermediate levels dominated by technological (based on the teacher's closed planning of activities, in accordance with a “hard” inductivist-empiricisit view of the scientific method) and spontaneist (based on the students' interests, on learning by spontaneous discovery, and on a “soft” view of inductivism and empiricism, according to which the students' mere observation of reality will impregnate them with the knowledge that it contains) tendencies, and takes the most innovative constructivist models as referents (based on contrasting, in a process oriented by the teacher in a community-of-learning framework, the students' ideas and interests with other potentially relevant information, so as to stimulate their critical questioning and evolution).

For the cognitive map analysis, we considered two contraposed models — the first more technical and traditional, and the second more in harmony with current educational and epistemological conceptions, and which we shall generically term the up-to-date or constructivist model.

In the image of science category, the more traditional model is the empiricist-inductivist model which stresses the justification of knowledge on the basis of observations of reality, through an inductive scientific method supported by data obtained from experience. The other, more up-to-date, model is one which is more in accord with the orientations generically posited by the new philosophy
of science, which stresses the role of hypotheses, holds that observation depends on theory, recognizes the influence of psychological, social, and technological factors in the production of knowledge as well as the temporal status of that knowledge, and considers that there is not just a single scientific method to generate knowledge (Mellado et al., 2006).

In the learning and teaching science categories, the two models are the technical-traditional model in which we include the items relating to the traditional-transmissive, technological, and spontaneist models of Porlán et al. (1997), and the innovative-constructivist model which coincides with that of the same name in Porlán et al. (1997).

To construct each category's general cognitive maps, one begins by selecting all the statements corresponding to the traditional model and the negations of the statements corresponding to the constructivist model. Then the statements are linked from the more general and inclusive to the more particular, forming the cognitive map of the model or of the category. The technique is analogous to that used by Novak & Gowin (1988) for concepts.

Figure 1: Empiricist-inductivist map of the questionnaire on the image of science.

The hierarchy of propositions in the map was validated by the INPECIP's authors, and by a group of primary and secondary education teachers (Mellado, 1996). The process of validation of maps was
carried out by researchers of the Universities of Seville and Extremadura, comparing teachers’
cognitive maps from the INPECIP questionnaire with cognitive maps from interview, about both the
nature of science (Mellado, 1997) and science teaching and learning (Mellado, 1998).

In each map, the statements have to be kept independent even when they have the same meaning.
While this is at the cost of making the map repetitive, the idea is that if a subject's responses happen to
be different and contradictory then this situation will be reflected on the map. The construction of the
maps is in itself an evaluation of the questionnaire, since one readily detects internal contradictions or
when an item has been inappropriately assigned.

In the image of science
category of the INPECIP,
items 4, 21, 22, 40, 42, 44,
and 47 were assigned to
the empiricist-inductivist
model, and items 11, 23,
28, 38, 39, 51, and 55 to
the up-to-date model.

In the empiricist-
inductivist map of the
questionnaire on the image
of science (figure 1), we
included the statements of
the traditional model (4,
21, 22, 40, 42, 44, and 47)
and the negations of the
up-to-date model (not-11,
not-23, not-28, not-38, not-
39, not-51, and not-55).

Figure 2. Up-to-date map of the questionnaire on the image of science

In the up-to-date map of the questionnaire on the image of science (figure 2), we included the
statements of the up-to-date model (11, 23, 28, 38, 39, 51, and 55) and the negations of the traditional
model (not-4, not-21, not-22, not-40, not-42, not-44, and not-47). The procedure for the construction of
the maps corresponding to the science learning and science teaching categories of the questionnaire was analogous. The questionnaire thus has six maps — two per category.

To construct the teacher's personal maps, her responses to the questionnaire were assigned to the corresponding map in each of the three categories, eliminating the unanswered items. For the final draught of the personal cognitive maps, any gaps were eliminated so that there was a link between the resulting statements. The construction process is standard, so that, from the same responses, one obtains the same map, independently of each teacher's personal context.

**The stimulated recall interview**

The stimulated recall interview has been used in other work to study the beliefs of science teachers (Yerrick & Hoving, 2003). Our aim in the present study was to reconstruct the trajectory of Consuelo's career with the help of the 1993 and 2002 maps. This semi-structured interview was conducted by one of the authors using a script based on these two maps and consisting of some 100 questions. Subsequently, the number of questions was increased to 141. The interview, which lasted more than two hours, was audio-recorded. In the interview, the evolution of her maps over time was compared, and she was asked, in view of her maps, for her opinion about the stability of or the change in her conceptions, and the factors that might have influenced that stability or change. Consuelo took no part in preparing the script, and up to this point her role was that of informant.

From that moment onwards, Consuelo became an integral part of the research team, transcribing, coding, and analyzing the interview in accordance with certain categories that arose and were discussed with the rest of the team during the process of analysis. In a continuous process of metacognitive reflection, the teacher added new reflections as she was transcribing, coding, and analyzing the interview, and while she was editing the results and conclusions.

Once the interview had been transcribed, each response was numbered and each phrase corresponding to an independent unit of information was encoded. For example, question 76 was encoded into three units of information — 76.1, 76.2 76.3:

76. - And you said that what is provoking this change is, for one thing, that you feel surer, you do not have to prove anything. But is there something that, at a given moment, helps you, gives you a push to start the changes?

- Yes, yes, [first because for me it is a personal satisfaction]¹. I, on seeing that my students… [for me, the most motivating are the students, yes]². Then, as I have had the opportunity of keeping in contact with many of them, [for me it is very motivating and very instructive what they can tell you at a given moment, including bad things, no?]³

In a first quantitative analysis, a system of matrices was constructed with the response codes. The rows corresponded to the categories described above: the image of science, science learning, and science teaching, to which we added a fourth on change in general. The columns corresponded to the
codes of the changes that had taken place in their conceptions, so that in a first quantitative analysis we were able to determine the aspects in which their conceptions had changed.

A second quantitative analysis was aimed at determining the factors that had stimulated or hindered change. To this end, we constructed a matrix with the same 141 rows corresponding to the items of the interview arranged into the four categories. For the columns, we established six categories into which we divided the factors that stimulated or hindered change: her students; her colleagues; the school; the curriculum; teacher education; and the teacher's personal characteristics. Each of these categories was divided into two subcategories — one for the factors that acted as stimuli or causes of change, and another for those which hindered or completely impeded change.

Finally, on the basis of the evolution of each category’s cognitive maps and of the quantitative tables from the interview, a qualitative analysis was made of the changes detected and of the causes that stimulated those changes or of the obstacles that impeded or hindered them. The annotations made by Consuelo regarding her reflections throughout the process were progressively added to the qualitative analysis, labeling them as "Reflections a posteriori" to differentiate them from the numerically coded interview.

RESULTS

The discussion of the results will be divided into three categories: the nature of science, science learning, and science teaching. Each will include general reflections on educational change, Consuelo’s 1993 and 2002 cognitive maps corresponding to that category, the evolution detected during the qualitative analysis of the interview results and of the subsequent reflection, and the causes of or obstacles to change.

Figure 3. Cognitive maps representing Consuelo’s empiricist-inductivist tendency with respect to the image of science in 1993.
Nature of science

In 1993, in the image of science category, Consuelo expressed agreement with items 4, 11, 21, 22, 28, 39, 40, 42, 44, and 51, and disagreement with items 47 and 55. The map representing her traditional tendency was constructed with items 4, 21, 22, 40, 42, 44 and not-55 (figure 3).

The map representing her more up-to-date tendency was constructed with items 11, 28, 39, 51, and not-47 (figure 4). Viewing the two maps gives one an overall picture of her conception of the nature of scientific knowledge. In 1993, her conception of the nature of science had features from both models, although there was a marked empiricist tendency.

In 2002, the teacher expressed agreement with items 11, 28, 38, 39, 51, and 55, and disagreement with items 4, 21, 42, and 47. These responses are all associated with the more up-to-date model, and gave the map of figure 5. In this year, none of the teacher's responses were attributable to the traditional conception, so that there is no cognitive map corresponding to this tendency.

One observes that, in the span of nine years there had been a notable evolution of this teacher's conceptions about the nature of science, from the empiricist model that predominated in 1993 with incipient up-to-date features, to the complete predominance in 2002 of a model that is more in accord with the new philosophy of science.

In the interview, she confirmed that there had occurred a considerable change in the aspects that condition human thought. In 1993, she did not believe that scientific thought was conditioned by subjective and emotional aspects. In 2002, however, she considered that there exist many conditioning factors, both social and psychological.

Figure 4. Cognitive maps representing Consuelo’s up-to-date conception of the image of science in 1993.

I believe that scientists do not come to their work free of any type of bias, opinion, or emotion, but rather, at the same time as they are individualized by multiple more or less subjective aspects, they have to search for information that contextualizes the work that they are going to undertake (20.1).

I presently consider that the development of scientific work and change of theories is enormously conditioned by aspects that are social (38.1), religious (38.2), technological (38.3), and related to professional education (38.4), and also by the students’ learning process.
Likewise, in 1993 she considered that the scientific method should be aseptic and objective, follow certain steps, and neither be influenced by anything nor take into account preceding theories that could affect the development of the process. In contrast, in 2002 she had a more open view of the scientific method.

My thinking on scientific method has changed. Now, mistaken or not, I consider that scientific work has to be disciplined, but not necessarily in the order of the steps traditionally considered in empiricism (21.1).

Figure 5. Consuelo’s cognitive map of the image of science in 2002.

Initially, she was unaware that her thinking about science was strongly empiricist, because she had never stopped to reflect on the topic, and because she was imbued with the implicit idea of science that had been transmitted to her during her education to become a teacher. At the beginning of their career, it is usual that teachers regard topics related to the nature of science as being less significant for them. Instead, they are more concerned about the daily routine and the problems of managing the classroom (Abd-El-Khalick et al., 1998; Roehrig & Luft, 2004). Subsequently, her idea of science was progressively transformed as a consequence of her own teaching experience.

In my opinion, after obligatory secondary education and pre-university studies, we are impregnated, at least I was, with a systematized and inflexible idea of scientific method which is not clarified during university studies, and which, in my case, has been progressively modified over the course of the last fourteen years of classroom practice (21.1).

When you are finishing university, and even during your first years of work, you do not stop to think about the questions commented on previously (23.2), and only later, with reflection on your own teaching practice, do you begin to become aware of the evolution that, on occasions without your realizing it, you have undergone (23.1; 23.4; 33.1).
In analyzing the causes of and obstacles to change in her conception of the nature of science, she made hardly any direct references to students, colleagues, or school, and only a passing allusion to the closed curriculum being an obstacle to teacher change. She also considered to be obstacles the image of science transmitted by textbooks.

The textbooks make no great contribution to clarifying these conceptions (25.1), and during your degree course and when you begin your career you do not ask yourself these sorts of questions about the textbooks (23.3), really "you do not stop to think" (33.2).

Most of the direct references were to initial professional education, which she regarded as an obstacle against changes in her empiricist conceptions about science.

It seems negative to me that, in this case, a biologist could not take any course related to teaching science as part of the undergraduate program, even if it were to be optative in character (34.5; 34.6; 34.7).

During the undergraduate program, there is no attempt to favour changing some of the conceptions of science, such as, for example, the scientific method (15.1, 26.1). Maybe because the stereotype is developed during pre-university secondary education (15.2). At university the knowledge is taken for granted (28.2).

Science learning

Consuelo's conception of science learning, both in 1993 and in 2002, was clearly linked to the constructivist model. In neither year did she express agreement with the items associated with the technical-traditional orientation.

In 1993, she agreed with items 5, 8, 32, 33, 50, and 54 and disagreed with items 19, 24, 27, 35, 41, and 48. In 2002, her responses were very similar, the only variations being that she did not define her standpoint on item 27, which is similar in content to item 50, and expressed agreement with 14 and disagreement with 46. In view of this similarity, we elaborated a single cognitive map for this teacher's conception of learning in 1993 and 2002 (figure 6). The two items (14 and not-46) that appear in the 2002 map, but not in that of 1993, are presented in italics.

In the reflections that she made during her analysis of the interview, she remarked that there had been less change in her ideas on learning from 1993 to 2002 because her greatest change in this aspect had already taken place during her first years of teaching, beginning in 1989 when she began to give classes. The fundamental factor that stimulated change during that period was becoming aware of the existence of the students' alternative ideas. As in other studies (Hewson et al., 1999b; Lucio, 2001; Macedo et al., 2001), knowledge of the students' alternative ideas has shown itself to catalyse reflection and change on the part of teachers.

One thing I have no doubt about is that the student does not come to the classroom as if one were dealing with a blank page. They have a [body of] previous experience that it is impossible to obviate when it comes to learning (56.2; 70.1).

I began to become aware of the existence of the alternative ideas during my first years in the profession, and
above all it surprised me that these ideas affected people of very different characteristics and educational backgrounds. Moreover, I was intrigued by the persistence of the said conceptions which were even manifest in science teaching professionals. The knowledge of the existence of these pre-existing ideas has, in my opinion, favoured the consolidation of a more constructivist form of teaching. (Reflection a posteriori.)

As in the teachers analyzed by Carvajal and Gómez (2002), Consuelo's conceptions on learning were always ahead of her epistemological conceptions, and the process of reflection on learning influenced her conception of science. For the aforementioned authors, teachers who tend to empiricism in epistemological aspects and to constructivism in learning reveal an incipient process of reflection that leads them to confront their empirical view of science with their students' learning process.

**Figure 6.** Consuelo's science learning cognitive map in 1993 and 2002.

During her process of analyzing the interview, Consuelo noted marked parallels between the evolution of her conceptions about science and the change in her thinking about the development of educational practice, and especially about the existence of alternative ideas held by the students.

Perhaps the closest analogy was in the subjective aspects that condition both the beginning of a scientific research study and the beginning of any type of learning. Progressively, the idea of the student as a "blank page" to be written on, or of the rigorously objective researcher, free of any type of bias, has given way to another more realistic idea — people who face their respective challenges with previous experiences determined by aspects that are social, religious, educational… (Reflection a posteriori).
Her initial epistemological absolutism, which for Jiménez and Wamba (2003) and Porlán et al. (1997) acts as an obstacle to change, was progressively modified as she became aware of the students' alternative ideas, and compared their learning process with the process of construction of scientific theories.

At the present time, I believe both in the value of mistaken or incomplete theories for the development of scientific knowledge and in the importance of using the students' errors in the construction of their knowledge … (Reflection a posteriori).

Consuelo reflects on the significance in her development of realizing that she had not to limit herself to conceptual knowledge, but that procedural knowledge was also important, especially in the process of problem solving. Other studies coincide in noting that novice science teachers plan almost exclusively by conceptual content (Aguaded et al., 1998). A greater emphasis on developing activities that foster the learning of processes could be an indicator that the teacher is beginning to change towards more innovative orientations (Bartholomew & Osborne, 2004; Martínez-Losada & García-Barros, 2005).

As a teacher, there came a time when I began to see that procedures meant something more than I had thought up to then, and that they included my form of working with the students, how I presented the problems for them to solve or how they themselves expressed those problems (61.1), and that understanding the concepts was not the only important thing (69.1).

Now I try to get them to use what they learn in some other way, to relate it, to "hook" it onto pre-existing ideas, to make comparisons, to extract information, to apply it… (73.1). I believe that problem solving is fundamental in learning (56.1; 57.1), without forgetting the need for theoretical knowledge and the use, when learning requires it, of memory.

She explicitly recognizes her students and colleagues as stimulators of change. With respect to obstacles to change in her conceptions about learning, she notes the high number of students per class, the rigidity of the curriculum, and the sparseness of her initial teaching education.

Concerning the students' influence in the development of educational change, I have detected both negative and positive aspects. Among the former, the high number of students (8.3; 10.3) and the work that this involves in correcting class work and examinations (8.5; 8.6). Among the latter, the fact that the demands that the student makes "oblige" you to reflect on the teaching-learning process so that you can reach them effectively (3.3).

With respect to the influence of my professional colleagues, in my work or outside it, on the change that I perceive over the course of the last ten years, this is summed up in the following aspects: I regard as positive the fact of having listened to the points of view of other professionals (3.2), since there are some who are truly active and concerned about teaching (7.1). I believe that an advantage is the stability of the teaching staff (7.2) and the fact that, in general, they are fairly open to change (7.3).

In the study carried out by Luna and García (2003) on a secondary education biology teacher with twenty years of experience and an innovative profile, the teacher's stability in the school was also a determining factor, since it gave him the security needed to set in motion a long-term process of innovation.
Science teaching

With respect to science teaching, in 1993 the teacher expressed agreement with items 1, 10, 13, 16, 25, 36, 43, and 45, and disagreement with items 2, 6, 9, 17, 20, 30, 31, 37, 52, and 56. The cognitive map representing her traditional tendency in science teaching in 1993 (figure 7) was constructed with items 1, 43, not-52, and not-56. The cognitive map representing her constructivist tendency in science teaching in 1993 (figure 8) was constructed with items 10, 13, 16, 25, 36, 45, not-2, not-6, not-9, not-17, not-20, not-30, not-31, and not-37.

Figure 7. Cognitive maps representing Consuelo's technical-traditional conception of science teaching in 1993

Thus one already observes in 1993 a constructivist oriented conception, although she still shows agreement with some items attributed to the traditional model of teaching.

In 2002, her constructivist tendency is even clearer. She expressed agreement with none of the statements attributed to the traditional model. In this year, she agreed with items 10, 13, 16, 25, 36, 45, 52, and 56, and disagreed with items 6, 7, 9, 17, 21, 30, 31, and 43. Figure 9 shows the resulting cognitive map for her conceptions of science teaching.

In the interview, in reflecting on the changes in her model of teaching, she notes that, in her first years of teaching, she had an intuitive idea of the teacher which could be considered close to the traditional-transmissive model, centred more on the teacher and the content than on the students' learning.

When I began work in 1989, I had an idea of how a class should be like (74.1), or rather I had a general concept about teaching, teachers, etc. (74.2). I understood that the teacher had to repeat something, nothing more, as often as necessary for the student to comprehend (77.1).

For Consuelo, this initial teaching model was fundamentally based on her own experience at school, and in her first years of teaching, she imitated the models of some of the teachers that she had had.

My initial and continuing professional education, and my experience as a pupil in my first years at school, have all contributed to developing my personal educational model. There is no doubt that, especially at the beginning of my career, there predominated the imitation of other educational models observed in the teachers that I had had (85.2).

As noted by Hewson and Hewson (1989) and Tobin et al. (1994) many novice teachers use
pedagogical methods that are very similar to those they preferred in their own teachers when they were students, or simply teach in the same way as they themselves were taught.

Consuelo recognizes that this initial traditional-transmissive model began to evolve progressively from the beginning of her career. Indeed the maps of the 1993 questionnaire, four years after she began to teach, already reflected a distancing from the initial model — an evolution towards a much more flexible model of teaching coherent with a constructivist orientation. She continues holding to this constructivist model at the present time. She observes that in-service education might have contributed to this evolution, and again emphasizes the importance of procedures in this change of orientation.

**Figure 8.** Cognitive maps representing Consuelo's constructivist tendency view of science teaching in 1993.

That initial model has been and still is progressively changing. The first years, I laid a lot of stress on the concepts (95.1), and now I am working much more on the procedures. In the programming, it is perhaps that which I take most into account (94.4).

Now I believe that, fundamentally, I do not have to teach the students concepts. I have to give them keys (112.1), methods (112.2), study techniques (112.3), and, in sum, confront them with their own difficulties (113.2) and give them weapons with which to construct their own learning (113.3).
The changes have been progressive, from an initial model centred on the content and on herself as teacher to one centred on the students and on learning.

Progressively, and almost without my realizing it, my concerns regarding science teaching have varied a lot. It is as if, with experience, you stop worrying about yourself (114.4). The students have come to occupy a different function to that of my first years in teaching. The initial preoccupation that you feel for the role you yourself play in teaching passes to the student, who is used as the starting point in the development of the teaching model (Reflection a posteriori).

Figure 9. Consuelo’s cognitive map of science teaching in 2002.

The teacher’s role in the students’ learning should be closely related to their pre-existing ideas. Bartholomew & Osborne (2004) note that, in the process of change, teachers have to make a change of their own from a role in which they transmit knowledge, to one in which they facilitate learning.
Consuelo, too, stresses her change of role, which she expressed in terms of the metaphor “a guide to learning”.

The role that the teacher should take on is that of a guide to learning. It is obvious that the teacher’s clear and concise explanation is not enough for learning to take place (58.1). From my point of view, we should help the student to reconcile what they bring from behind with what we want them to learn (56.3).

An important aspect of educational change is that teachers make changes in their conceptions and educational practices when they are able to construct new roles by way of a process of critical reflection at the same time as adopting or constructing new metaphors that are compatible with the changes (McRobbie & Tobin, 1995; Mellado et al., 2006; Tobin et al., 1994).

Her preoccupation with the students leads her to take them much more into account throughout the process. This includes programming, which is far more flexible, being adapted to the students' needs, and with their being involved in its preparation.

In designing the programming, and above all in the day-to-day in the classroom, over the years I have been taking ever more account of what the students demand (85.4). I believe that the students must take part in these designs (89.1).

In her responses, she expressed the importance of affective and social aspects in her evolution as a teacher. At the same time, she recognizes that one of the greatest problems for teacher change may be their individualism.

I believe that change is enormously favoured by the personal satisfaction that you feel when you find that the actions you are carrying out are having a positive result (76.1).

I always thought that the fact of giving classes would satisfy me, but I was unaware of the personal relationships that I was going to establish with the students and their families and with colleagues, and these relationships have provided me with many more satisfactions than disappointments (137.1).

If each process that the teacher develops in the classroom were shared and discussed with colleagues, I believe that it would redound considerably to the benefit of the teaching function. At bottom, I believe that one of the great problems of teachers is their individualism (123.1).

Consuelo also expresses concern for a "good atmosphere" in the classroom. Tobin and Fraser (1990) indicated that students seem to perceive how good a science teacher is according to the social climate generated in the classroom.

For teaching-learning to be effective and gratifying, we need to create a good atmosphere (124.4), to speak with our students' parents (124.5) and with the students themselves (124.6).

Another of the reasons that Consuelo noted for the gradual evolution of her model of teaching is represented by the results of the students' learning. Reflection on the students' achievements and the reinforcement and support that the teacher receives from them are a major stimulus for change (Tobin et al., 1994), since change is closely related to "the harvesting of fruit" (Climent, 2002) in the students' learning process.
With time, these ideas have changed, amongst other things because I did not see that major results were attained with them (77.2). I believe that my form of thinking now on science learning is more coherent (79.1). Now, I am aware of where most of the problems lie (79.4), although sometimes I do not know how to solve them or what instruments to use (79.6).

Reflection is an unavoidable mechanism that acts as a motor of change (119.2), and it arises in response to the dissatisfaction that appears fairly often, and which I believe is needed in order for change to begin (129.1). Yes, I am someone who is continually dissatisfied, but I am not a negative person. This I believe would be a characteristic that would hinder any project that one undertakes (129.2).

Although she recognized that there are unresolved problems such as that of evaluation. She did not see as an obstacle, however, the existence of unresolved problems in science teaching or learning. Rather she considered the certain dissatisfaction that they caused her to present an opportunity for reflection and improvement.

Maybe, my greatest confusion centres on evaluation. I can not manage to reconcile what evaluation is, what I hear it should be, with what I actually do in practice (79.2).

In the case studies of Glasson & Lalik (1993), the evolution of one of the teachers towards a more constructivist orientation made her feel dissatisfied with the systems of evaluation that she was using. Nevertheless, as in the case of Consuelo, she found it very difficult to introduce new systems.

In her analysis specifically of the factors that might have influenced the change in her conceptions of science teaching, there stand out the many references — always positive and as favouring change — to her students and colleagues at work.

I believe that I related well to the students (120.1), and I believe that this helps me and helps them for learning to take place. And as I note that the student responds well to cordial relationships, the change becomes consolidated (141.1).

My colleagues have influenced me in the evolution of my thinking on science teaching and in the changes detected in my educational model (119.3). I give a lot of importance to team work (119.4) and to good personal relationships with colleagues, besides the merely professional relationships (122.1). They allow opinions to be exchanged about each other's work, whether positive in nature or negative (123.2), and let you feel more sure about the actions you have carried out, since they are based on the contributions of various teaching professionals (123.3).

As was noted by Bell & Gilbert (1994), social aspects are fundamental for change. In a case study of a secondary education science teacher, López (2000) reports that team work with a colleague was the determining factor in that teacher's evolution. The context especially influences novice teachers (Munby, Cunningham & Lock, 2000; Simmons et al., 1999).

Finally, Consuelo stressed that she now believes that there is a far greater coherence than some years ago between her scientific thinking, her ideas on learning and teaching, and her classroom practice.

Now, my aim is for my thinking on science learning to be reflected in the classroom (35.1), and I take all the facts that develop during the process of learning to be relevant (39.2).

One of the aspects in which I consider that there has been a change is that related to the maintenance of a certain coherence between my thinking and my classroom practice. In my first years of teaching, I had a set idea of what a class should be like (9.2): silent and disciplined. At bottom, I thought that on many occasions a class would lend itself to discussion and debate, and that the important thing was to encourage it by maintaining certain "rules of play" (9.3). Now I try to get what I do to be in consonance with what I think (9.4), and I work to give meaning to the
fact that the student's confidence in the classroom is not at odds with the discipline necessary in a class (9.1).

CONCLUSIONS AND IMPLICATIONS

The results indicate that Consuelo's conceptions underwent a progressive and gradual evolution, and were often out of phase with each other. Indeed, change is not linear, but is a complex process involving numerous factors that can be potential hindrances and make effective change difficult (Davis, 2003). The teacher's initial conceptions about the nature of science in 1989 were a marked empiricist tendency since this was the, often implicit, message that she had received during her early professional education based on scientific content. Her initial conception of science teaching was centred on the teacher as transmitter of conceptual content which the student had to learn. This image of the teacher had been obtained from her own experience as a student at school, and in her first years of teaching, she imitated the models of some of the teachers that she had had.

While there was a gradual and progressive evolution of her conceptions right from the beginning of her career, this evolution did not take place simultaneously in all of those conceptions. During her first four years in the profession, until 1993, her conceptions about science teaching and learning evolved from a teacher and content centred model to a more student centred model. There was practically no movement, however, in her basically empiricist conception of the nature of science. The fundamental factor stimulating change during her first years as a teacher was becoming aware of the existence of the students' alternative ideas — ideas which the students bring with them to the classroom and which in many cases persist despite the teacher's explanation. Indeed, knowledge of the students' alternative ideas has been found to be a catalyst of reflection and change in teachers. As is observed by Gunstone & Northfield (1994), a teacher's changes do not occur in the abstract, but in the context of specific content and activities of his or her subject.

Another important factor in Consuelo's change of orientation was realizing that she did not have to restrict herself to conceptual knowledge, but that she had to include procedural knowledge, especially in the process of problem solving. Furió & Carnicer (2002) and Gil-Pérez (1993) also note, from a constructivist standpoint, that the changes need to affect conceptual, methodological, and attitudinal aspects of the teaching community.

The cognitive maps of 1993 already reflected a basically constructivist conception of both science teaching and science learning that was progressively reinforced through to 2002. Her current conception of science teaching/learning is student centred, instead of the earlier protagonism of the teacher and the textbook. Hence, far more account is taken of the students throughout the process. The teacher's role in the classroom, and hence in the students' learning, is closely related to the fact of having been aware of the pre-existing ideas of the students, with the result that her role changed to one
which had adopted the metaphor of “a guide to learning”.

The students' results in learning were another of the reasons that Consuelo cited for the gradual evolution of her teaching model, although she still recognizes that there are unresolved problems such as that of evaluation. The existence of unresolved problems in science teaching and learning, however, although they cause her a certain dissatisfaction, is not seen as an obstacle, but as an opportunity for reflection and improvement.

In her responses, she expressed the importance of affective aspects in her evolution as a teacher. While the direction of her changes was that of improving the teaching/learning process, it was always by doing what gave "personal satisfaction" and was found to be "gratifying" both to her and to her students. The present results show the need to consider the personal aspects that affect the teacher's feelings. We therefore believe any proposal for professional development has to take account of these personal aspects, strengthening the teacher's self-esteem, recognizing positive contributions and using them as the basis for the construction of change (Copello & Sammarti, 2001; Zembylas, 2002).

Social aspects are also fundamental. The teacher is part of a school, and it would be very difficult for change to occur, and even more so for it to be consolidated, individually and countercurrent to the school's educational "culture" and the socially accepted forms (Hargreaves, 1996; Sánchez & Valcárcel, 1999). Consuelo noted the importance of the relationships with her colleagues, and that teachers' individualism may be one of the obstacles to teacher change. For her, teamwork not only aids professional development, but also, in sharing experiences and frustrations, it can constitute an emotional and affective support for the teacher.

Her conceptions about the nature of science had remained practically unaltered, with a basically empiricist orientation, during her first years of teaching. This was not the case with her conceptions about teaching/learning. These had gradually evolved from a teacher and conceptual content centred orientation to one centred on the student and learning.

We saw in the results that, while she was analyzing the interview, Consuelo was discovering marked parallels between the evolution of her conceptions about science and her changing thinking about how she taught, most especially about the existence of the students' alternative ideas. Her initial epistemological absolutism about science underwent modification later, as a consequence of the modification of her conceptions about learning. Becoming aware of the existence of the students' alternative ideas and their consequences in science learning and teaching was the decisive cause of her adopting a less dogmatic conception of the nature of science. Tsai (2006) also point out that the reflection about student alternative conceptions is an important factor for changing teachers' views about science.

The last conclusion that we would highlight is that the degree of consistency between the different
conceptions differed greatly according to the period. There was initial consistency between her traditional conceptions of science and teaching/learning. Four years later, in 1993, these two sets of conceptions were out of phase with each other. Her conceptions about the nature of science had stagnated in the empiricist orientation, while her conceptions about science teaching/learning had evolved towards constructivist orientations. By 2002, as a consequence of a long continual process covering nine years, we observed that there was again coherence between her scientific thinking and her ideas on science teaching and learning.

With respect to the implications of the present study, Consuelo made numerous references to her classroom practice, and to how it had been evolving simultaneously with her conceptions on science teaching and learning. Nevertheless, we have no direct data on her actual practice. A teacher's reflection on his or her own conceptions is known to be an important factor for there to be a beginning towards changing classroom practice (Briscoe & Wells, 2002). Several studies have found, however, that, depending on the teacher and the context, conceptions and practices are often out of phase with each other, and even plainly in contradiction, and that changes in one are not necessarily accompanied by a change in the rest (Freitas et al., 2004; Lederman, 1992; Marx et al., 1998; Mellado, 1997 & 1998; Meyer et al., 1999; Roehrig & Luft, 2004; Simmons et al., 1999; Solís & Porlán, 2003). There may be no transfer of science teachers' conceptions of science into classroom practice if the teachers lack schemes of practical action that are coherent with their beliefs (Furió & Carnicer, 2002; Gess-Newsome & Lederman, 1993; Lederman, 1999; Tobin, 1993). This lack of syntony is particularly marked in novice teachers who may have student-centred conceptions, while conserving teacher-centred teaching behaviour (Simmons et al., 1999). We believe there is a need for more long-term longitudinal studies that monitor both the different conceptions and the classroom practice of the participating teachers. In this line, we are currently working with secondary education science teachers who have different levels of experience.

As in many other studies on Spanish secondary education teachers, we believe that their initial content-centred teacher education, without either psycho-pedagogical professional knowledge or knowledge of science education, makes it unlikely that they leave university with an innovative profile and the capacity to self-regulate their own changes. We think that initial teacher education has to integrate academic knowledge, personal conceptions, and practical knowledge, and contribute to the prospective teachers' generating their own pedagogical content knowledge. Since propositional academic knowledge is not transferred directly into practice, teacher education has to provide students with the opportunity—via a metacognitive process of reflection—of becoming aware of their own conceptions and classroom practice when they are teaching their particular subject matter. They will then be able to self-regulate and re-structure these facets of their teaching, and progressively develop a
personal teaching model (Sanmartí, 2001).

The study has shown that teacher changes are complex, gradual, and frequently get out of phase. We believe that the professional development of experienced teachers should not be approached as a matter of "change" by substitution of the preceding models, but rather as an internal process of "growth", "evolution", and gradual "development" starting out from what they already think and do (Day, 1999). The basis should be the real problems of science teaching and learning, i.e., the teacher's everyday concerns, encouraging and supporting metacognition, motivation, collaboration, and the teachers' commitment to their own professional development (Hargreaves, 1996). In this process, teachers evolve from their own individual situation and context towards a greater complexity in reflection and in how they teach science (Vázquez et al., in press).

REFERENCES


Appendix: INPECIP questionnaire (Inventory of Teachers' Pedagogical & Scientific Beliefs)

1. The students learn scientific concepts correctly when they do practical activities.
2. The teacher must plan in full detail the tasks to be done in class by the teacher and the students to avoid improvisation.
3. Didactics is today regarded as a scientific discipline.
4. Scientific theories, obtained at the end of a methodologically rigorous process, are a true reflection of reality.
5. The starting point for scientific learning should be the students' spontaneous ideas.
6. Doing problems in class is the best alternative to the traditional master-pupil method of teaching science.
7. The correct way to learn science in primary education is by applying the scientific method in the classroom.
8. Learning will be meaningful if the students are capable of applying it to different situations.
9. The teaching method is the form of presenting the scientific content.
10. The library and the classroom bookshelf are indispensable resources for teaching science.
11. In the observation of reality, it is impossible to avoid a certain degree of distortion introduced by the observer.
12. Didactics has to define principles and norms to guide and orient educational practice.
13. Teachers have to make teaching tasks compatible with those of investigation into the processes that take place in their classes.
14. The students usually involuntarily distort the teacher's spoken explanations and the information in the textbooks.
15. The teacher must replace the sequential list of topics to be covered by a list of central points of interest that cover the same content.
16. The teaching/learning processes that take place in every class are complex phenomena involving innumerable factors.
17. The students should not intervene directly in the programming and evaluation of the activities in class.
18. The aim of Didactics is to describe and understand the teaching/learning processes that take place in the classroom.
19. The students do not have the capacity to form conceptions about the natural and social world spontaneously, by themselves.

20. Organized and hierarchized objectives should constitute the essential instrument guiding educational practice.

21. The scientific observer should not act under the influence of previous theories about the problem being studied.

22. All scientific research begins with the systematic observation of the phenomenon under study.

23. Human knowledge is the fruit of the interaction between thought and reality.

24. Science learning takes place when the teacher explains a scientific concept with clarity and the student is paying attention.

25. Contact with reality and laboratory work are indispensable for scientific learning.

26. The school's organization must be based on flexible timetables and groupings.

27. The science learning that is essential for the students to assimilate in school is that which is related to the comprehension of concepts.

28. The thinking of human beings is conditioned by subjective and emotional aspects.

29. The basic objective of Didactics is to define the techniques that are most appropriate for quality teaching.

30. Classroom work should be organized around the content.

31. Evaluation should be centred on measuring the level that the students have reached relative to the expected goals.

32. Learning is improved if the students relate the new content to their previous knowledge.

33. Scientific learning is meaningful when the students find a personal interest in what they are learning.

34. A good textbook is an indispensable resource for science teaching.

35. To learn a scientific concept, the student has to make a mental effort to memorize it.

36. The teacher constructs his or her own method of teaching science.

37. Science teaching methods based on student research do not stimulate the learning of specific content.

38. The researcher's activity is conditioned by the intuitively suggested hypothesis about the problem under study.

39. Scientific knowledge is generated by our capacity as human beings to pose ourselves problems and imagine possible solutions to them.

40. The effectiveness and objectivity of scientific work resides in following faithfully the ordered phases of the scientific method: observation, hypothesis, experiment, and construction of theories.

41. The students show that they have learnt by correctly answering the questions that the teacher puts to them.

42. The scientific method fully ensures objectivity in the study of reality.

43. To teach science, it is necessary to explain the topics without hurrying, so as to facilitate learning.

44. The researcher tests the truth or falsehood of the working hypothesis through experiment.

45. Science learning based on work with the textbook does not motivate the students.

46. Conceptual errors should be corrected by explaining the correct interpretation as often as the student needs.

47. Science has evolved historically by has evolved historically by the accumulation of true theories.

48. Students are more or less clever according to their innate abilities.

49. In the science class, it is advisable that the students should work in teams.

50. Students' scientific learning must cover the data and concepts of science, and the processes of the scientific method (observation, hypotheses, etc.).

51. The research process is directed by hypotheses.

52. Most science textbooks do not facilitate comprehension and learning.

53. Didactics advances by means of processes of theoretical and practical research.

54. For learning to be meaningful, it is important that the students feel capable of learning by themselves.

55. Experiment is used in certain types of scientific research, but not in others.

56. Science teaching based on spoken explanation of the topics encourages the students' rote learning of the content.