Teaching as Integration of Theory and Practice. Obstacles for the Professional Development: The Case of a Science Teacher

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Abstract: The work described here is a case study of a secondary education science teacher about how action-oriented reflection and action itself interact, and their influence on professional development. The study was carried out from two different viewpoints: a study with a qualitative orientation on the one hand, using diverse data collection and analysis instruments, and collaborative action-research on the other, to form the backbone of professional development. The two approaches enabled us to analyze the processes of change and complexity in professional development. In our theoretical outline, we stressed the concepts of reflection which sustain the theoretical-practical dialectic, and of complexity which was seen to be a progression hypothesis of central importance, and in which we distinguished three dimensions: technical, practical, and critical. The results showed the teacher to be in transition from a technical to a practical dimension, with both her reflection and her classroom practice in the process of becoming more complex, and with the two being closely integrated, reflecting the intimate relationship between reflection and action. It was also found that she had a hard core of obstacles impeding her professional development in the terms considered.

Introduction

In Spain, for two decades, we have been subjected to a continuous process of educational reforms, especially in the secondary education. Recent studies with Spanish secondary science teachers (Banet, 2007; Pro, 2006), however, show that, although the teachers use the innovative discourse of the reforms formally, in their classrooms most of them continue to use the same methods of teaching that they used before, generally with the teacher as the central figure and based on the transmission of conceptual knowledge through the teacher and the textbook. 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 (Dori & Herscovitz, 2005; Tobin et al., 1994).

Understanding the processes of science teacher professional development has become one of the principal themes on the agenda of science education research (Gess-Newsome, 2001; Hewson, 2007; Marcelo, 2001; Marx et al., 1998; Schneider et al., 2005), and is an essential element in the planning and practice of teacher education programs (Banilower et al., 2007). An important topic in research on teacher education and professional development is the process of change in science teachers and the

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factors that favour or hinder it (Davis, 2003; Hargreaves et al., 1999; Mellado et al., 2006).

In this paper we describe a case study of an experienced secondary education science teacher participating in a collaborative action-research work program. We analyse the evolution and mutual integration of the teacher's thinking and practice, and with the obstacles that were involved.

Professional development in experienced science teachers

Several studies have found that teachers do not easily change their conceptions, and even less so their educational practices, and depending on the teacher and the context, conceptions and practices are often out of phase with each other, and even plainly in contradiction, especially for novice teachers, and that changes in one are not necessarily accompanied by a change in the other (Brown & Melear, 2006; Freitas et al., 2004; Lederman, 1992; Marx et al., 1998; Mellado et al., 1998; Mellado et al., 2008; Meyer et al., 1999; Roehrig & Luft, 2004; Simmons et al., 1999; Solís & Porlán, 2003; Tsai, 2002).

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 (Jeanpierre et al., 2005; Lee et al., 2004; McRobbie & Tobin, 1995). Moreover, there exist conditioning elements that reinforce traditional models, and are obstacles to changing them (Reis & Galvao, 2004; Shwartz et al., 2005; Tobin, 1998; Verjovsky & Waldegg, 2005).

Previous research has shown that teachers' advanced concepts may not be converted into classroom practice if the teachers lack schemes of practical action that are coherent with their beliefs (Furió & Carnicer, 2002; Lederman, 1999; Mellado, 1998; Tobin, 1993). Also, Guskey (1986) holds that change in teachers' conceptions is the end result of a process preceded by changes in the teaching practices.

Research with experienced science teachers has also found that the process of change is continuous but gradual (Cunha, 2001; Peme-Aranega et al., 2008). Teachers do not usually make drastic changes. Instead, they progressively put into practice the ideas that seem to them to be important and at the same time attainable (Gunstone et al., 1993; Rogan, 2007).

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For these teachers, professional development can be presented as an internal process of growth, expansion, and increasing complexity of how they approach their practice (Greensfeld & Elkad-Lehman, 2007), based on what the teachers already think and do (Day, 1999; Mulholland & Wallave, 2005), on the real problems of science teaching and learning, on their everyday concerns, on their background (Henze, Van Driel & Verloop, 2007), and on the context in which they work (Jiménez & Wamba, 2003).

Professional development as the integration of reflection and practice

We stress the role that reflection plays in our theoretical framework, sustaining teachers' theoretical-practical dialectic. The concept of reflection has been extensively dealt with in the literature on teacher education and professional development (I'Anson et al., 2003; Pollard, 2002; Zeichner, 1987), with the metaphor being coined of the "reflective practitioner" (Schön, 1983) who relates reflection with teaching practice.

Educational change is stimulated by successive processes of metacognitive self-regulation, based on the teachers' reflection, comprehension, and monitoring of what they think, feel, and do, and of the changes that they put into effect. This involves awareness of what problems of teaching and learning might be improvable, elaborating new activities, materials, and teaching proposals (Powell & Anderson, 2002), putting them into practice in the appropriate context, successive reflection on their teaching and on the results in the pupils' learning, and comparing their practices with other cases to again revise and self-regulate them (Bañas-Sierra et al., 2009; Marx et al., 1998; Mellado et al., 2006).

The focus of our work is the context of conscious reflection, i.e., reflection that is capable of integrating rational and reflexive thought, that generates conscious theoretical and practical contextual knowledge, and that can be reported explicitly (Furlong, 2002). We are especially interested in understanding and interpreting reflection and its relationship with practice, as well as the processes of metacognitive self-regulation (Baird et al., 1991; Copello & Sanmartí, 2001; Gunstone & Northfield, 1994; Gunstone et al., 1993).

We have based our study on those authors who, with different terminology, establish various levels in teachers' reflection, from a more technical to a more critical level, passing through various intermediate levels (Carr & Kemmis, 1988; Elliot, 1999; Louden, 1991; Van Manen, 1977; Zimpher & Howey, 1987).

We establish the Complexity Hypothesis with three dimensions, both for reflection and for classroom practice: technical, practical, and critical (Vázquez et al., 2007a). The technical dimension (T.D.) is associated with the so-called technical rationality or effective instrumental application of educational knowledge. This leads to a space of self-consistent routines and patterns of action which feed back on themselves. The practical dimension (P.D.) assumes commitments to solving the practical problems that affect teaching and learning, and whose resolution guides reflection. It considers classroom practice to be a generator of knowledge for the teacher through reflection on experience and theory. The critical dimension (C.D.) also includes social and ethical criteria in the educational discourse, which adds complexity to practical problems. For the organization of classroom work, for example, in the reflection we investigate the references to competition as an impetus to learning (T.D.), to pupils' working in teams (P.D.), and to support for the most socially needy (C.D.). In the practice we study how the pupils are organized into groups: single, isolated from one another (T.D.), as free groupings (T.D.), or with groupings decided by the teacher on criteria of cooperation among peers and assistance to pupils with difficulties (C.D.).

In our hypothesis, professional development can not be designed as a change from one dimension to another but rather as a process of increasing complexity in which each dimension becomes more complex, from purely instrumental interests to social awareness and the emancipating role of education. In our approach, reflection both guides action and is guided by it in a process of mutual and convergent interaction.

The process of action-research in the work group

Professional change has to go together with personal and social development (Bell & Gilbert, 1994; Proweller & Mitchener, 2004), taking affective aspects into account (Friedrichsen & Dana, 2005), 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; 2000). Social aspects are fundamental for science teachers' professional development. The teacher is an integral part of the community of a school, and it is very difficult for change to be individually implemented, and even more so for it to be consolidated, against the current of that school's educational culture and socially accepted norms (Bell, 1998; Hargreaves, 1996; Mellado et al., 2006; Milicic et al.,

2004; Sánchez & Valcárcel, 2000).

There is sufficient evidence of the benefits of research strategies for the professional development of science teachers (Roth, 2007). However, the results of studies carried out by experts who themselves are outside secondary schools hardly ever reach the classroom, even though these studies may have been carried out "for" or "on" teachers. The investigations that have the greatest capacity to add to teacher education and the greatest likelihood of influencing actual practice are those done "by" and "with" teachers, in teams that cross disciplines and levels, where the teachers are not consumers of external knowledge, but co-producers and agents of change in the problems that really concern them in their classes (Cachapuz, 1995; Ritchie, 2008). This is the line of action-research programs, which have proved effective in promoting the professional development of science teachers (Baird et al., 1991; Lyons et al., 1997).

Sharing problems and seeking solutions in collaboration with other teachers reinforces professional skills and provides affective and emotional support (Bailey et al., 1999; Bell & Gilbert, 1994; Hanley et al., 2008). Action-research is a powerful procedure for the professional development of teachers, thanks to the cooperative action that it involves, and to the team work by means of which the teachers guide, correct, and assess their own problems, and take decisions in order to improve, analyze, or question their educational practice (Imbernón, 2002). This way of dealing with the subject requires medium and long term longitudinal studies, since the changes occur over long periods of time, and only longitudinal studies will show whether those changes are ephemeral or permanent (White & Arzi, 2005).

Research questions

Our research has a twofold purpose. The immediate goal is to obtain results that will shed light on the processes of reflection and practice in a group of teachers committed to curricular innovation and to their own professional improvement. And a longer term goal is to contribute, by means of action-research, to the professional development of all the participating teachers and researchers.

Our work forms part of an action-research program carried out in a state secondary-education school in a town of 20 000 inhabitants in the province of Huelva, located in the southwest of Spain. It was carried out by a teacher-researcher from the same school,

with four other teachers from the school and university science education researchers.

The teacher-researcher has a dual role. On the one hand, it is to act in the classical sense of a researcher, obtaining and analyzing a series of data that help to advance knowledge about teachers' professional development. And on the other, it is to act as a "facilitator" in the action-research group with the other participating teachers.

In the present article we will centre on the case of a teacher we will refer to as Marina, one of the teachers participating in the research. In another work (Vázquez-Bernal et al., 2008), we described the case of Ana, another of the participating teachers. Although the results are specific for each teacher, both are part of the same research group, so that the context, method, and presentation of the results have many aspects in common.

Marina is a Geology graduate, and she had eight years teaching experience when she joined the work group. Her administrative situation is that of an interim teacher, which gives her a certain degree of uncertainty as to her career prospects. Previously, she became involved in work groups on curricular innovation, so that the dynamics of collaboration are not new to her. She is a fairly shy person, although without any problems of communication, and she has established firm links of friendship with her colleagues.

The research problems will deal basically with the evolution and mutual integration of Marina's thinking and practice, and with the obstacles that were involved (Problems a, b, and c). We also wished to determine the influence of the action-research program on Marina's professional development (Problem d), while accepting that the results of this aspect may not be generalizable.

We summarize in the form of questions the problems that we set ourselves:

a) Is there a degree of convergence between reflection and classroom practice? How do they both evolve over time?

b) In which dimension of the Complexity Hypothesis is Marina situated, both for reflection and for classroom practice?

c) What kind of obstacles hinder the integration of reflection and classroom practice, preventing the desirable development?

d) Is it possible to base professional development on the integration and complexity of reflection and classroom practice? In what way can the program

of action-research influence teachers' professional development?

Research methods

To put into operation the process followed with the teachers, we applied the Kemmis & McTaggart (1988) action-research model, whereby successive methodological cycles of planning, behaviour, observation, and reflection are established. The work was carried out during two consecutive school years, 2001-2002 and 2002-2003, with students of the 3rd year of Secondary Obligatory Education (14-15 years old).

The five teachers at the secondary school (the facilitator plus the four participating teachers) held weekly meetings of from one to two hours from September to June of each school year. All the sessions of the two years were audio-recorded for subsequent analysis. In the planning cycle of the 2001/02 course, various actions were carried out with the teachers: completion of Wamba's questionnaire on Declared Initial Conceptions of (Wamba, 2001), with a Likert scale of responses (1, 2, or 3). Its purpose was to promote the teachers' reflection on aspects of science (what is scientific knowledge, how is it constructed and by whom, what uses does it have) and its teaching (what to teach and how, evaluating the learning). For example, in the area of "What is scientific knowledge?" the teacher expressed agreement with the item:

> "Scientific knowledge is a way of seeing the world that is organized and agreed on by a consensus of the scientific community, in which scientific concepts and models are faithful reflections of reality which can be equated with truth and are not temporary in character, there are no universal criteria to separate science from non-science, and it is of no significance for the validation of scientific knowledge whether or not different cultures accept it."

On the basis of the responses, we prepared a semi-open interview based on the items in the questionnaire. For example, in the interview we put the following question:

> "If science is a true reflection of reality and atemporal, how can it be consensual? Are other types of knowledge other than the scientific less rigorous? Must cultures adapt to scientific knowledge?"

The results of the interviews also revealed how their reflection had evolved by the end of the process.

In an initial phase of reflection prior to action in the classroom, teaching units were prepared taking as a basis each teacher's materials. The teachers decided to focus on the 14-15 year age group because they considered it the most problematic. The teacher

with the role of researcher-facilitator provided literature by specialists in the design of teaching units which was contrasted against the teachers' own practical experience, and served to help reformulate the units that were being used in the school. The topic chosen for the unit was "Structure of Matter/Solutions" by request of the researcher-facilitator, and accepted unanimously by the teachers because of its phenomenological closeness to the pupils' everyday experiences. With the aim of enriching the debate, readings were made on the topic of evaluation and its negotiation. These readings were strongly criticised by the teachers for whom they were just another lot of "new fads".

Simultaneously with the readings, the teaching units that were to be implemented in the classroom were prepared and adapted, as also were instruments to detect the students' problems, for which readings on evaluation were also scheduled. During the first phase of action/observation, the teaching units were put into practice and the sessions were video-recorded, with notes being taken to form part of the ethnographic records. These recordings were made without distinction by all of the participating teachers after preparation in the group, and centred on the occurrences and their timing as they happened in the classroom, with the teacher always maintained as the focus of attention.

In the case of Marina, 27 video sessions were recorded during the two school years, together with their corresponding ethnographic records. The teachers kept diaries in which they entered their thoughts and reflections after each classroom session. The entries to these diaries were made for just over one month per school year – the time that the teachers spent in implementing the teaching unit. Their average length was about 5000 words per teacher per year. To encourage and stimulate internal and external debate, and thus expand the horizons of their socialization, all the teachers had access to the recordings and ethnographic notes of their colleagues. After the period of implementation of the teaching unit, the group allowed themselves time to critically review their own and their colleagues' ethnographic recordings and notes. In general, they were very critical of themselves but reluctant to criticize their colleagues. A complementary vision to that of the teachers was provided with the help of selected pupils who kept their own diaries to which their teachers had access. These pupils were chosen by each teacher from volunteers after informing the families and receiving their permission. Each sample included some pupils with good academic results, some with

acceptable results, and some with learning problems. The teacher instructed them on how to keep a diary and what aspects they should focus on so that their criticism could help improve the teacher's work. These documents did not form part of the research analysis, but were used as a means of encouraging the teacher's reflection.

Analysis and reflection on the work was carried out by both the teachers and the students. The teacher-researcher designed statistical tools (descriptive and factorial) to detect the students' problems, sharing with the other teachers the tasks of analysis and interpretation of the results with the aim of mobilizing the teachers' cognitive resources and encouraging criticism. This first annual cycle was concluded by drafting reports at different levels – students, teachers, and researcher. These were again debated, and improvements proposed for the next cycle.

The second course began again with the spiral of action-research, basically similar to the previous year.

In the second year, the group of teachers were highly motivated, more sure of themselves, and keen to begin with the new year's experience. The group had attended meetings with other work groups from different towns, in which curricular innovations were discussed, with our group showing a high degree of cohesion in defending their work. Now, however, on the basis of the reflection on and analysis of the results of the previous year, the teaching units were re-drafted, in particular to include more practical activities. The readings and discussions in the work group focused on the teachers' own core interests, in accordance with their desires for change: pædagogical content knowledge, metacognition, and practical work in the science laboratory. During the phase of analysis/reflection with the instruments of the previous cycle, the group proceeded to the analysis of the results and the proposal of further improvements for subsequent cycles. The cycle ended with the final interviews with the teachers, taking as basis the Reflection Analysis Categories System (described in Annex-I), asking them openly which dimension they felt most identified them for each object of analysis.

Data collection and analysis instruments

We shall classify the instruments according to their methodological function: first order (data collection), second order (analysis category systems, theoretical and taxonomic models), and third order (presentation and interpretation of the data).

The reflection data collection instruments were the teacher's diaries and memos, transcriptions of the work group meetings, questionnaires, and interviews. This variety of instruments allowed us to undertake a triangulation from different perspectives. For the classroom practice, the instruments were the ethnographic notes and extracts from the videotapes of the class sessions, and other documentary sources such as the programs and teaching units, or the work produced by the students.

The fundamental instrument for data analysis, both for reflection and practice, was the Reflection Analysis Categories System (R.A.C.S.), shown in Annex I. We took as initial reference for the categorization the work of Wamba (2001), but some categories emerged from the data analysis itself, in a process that became ever more enriched as the investigation progressed (Vázquez-Bernal, 2006).

In order to elaborate the R.A.C.S., we considered six analytical frames: ideological, teacher education, psychological, contextual, epistemological, and curricular. These frames are organized into 21 structures/substructures in which we distinguished three dimensions (technical, practical, and critical), in harmony with the Complexity Hypothesis, We included in the ideological frame the influence of ideologies on the educational environment and on the relationship of the teacher with that environment. The teacher education frame included the education of teachers in general (understanding a teacher's capacity for reflection on the multiple facets of their work to be part of their learning process) and science education in particular. The psychological frame included the way in which the teachers view school-level learning and their understanding of the obstacles in the teaching-learning process, always considered from the teacher's perspective. In the contextual frame we included the interactive teacher-student relationships, and the social and temporal (scheduling) organization. In the epistemological frame, we included school-level knowledge and how the teachers perceive it, the criteria with which they select the sources of information, and the utility and construction of this kind of knowledge, considering therefore everything relating to the type of knowledge that is addressed in the classroom and its construction. Finally in the curricular frame we included the types of problems that are proposed in the classroom, the sequences of activities, the curricular material employed, and evaluation.

The codes associated with each category are four-letter acronyms. The first letter indicates the dimension (T: technical; P: practical; C: critical). The other three letters

are related to the meaning of each category. We shall use the codes in the representations of the analysis of the results.

The Practice Analysis Categories System consists of the psychological, contextual, epistemological, and curricular frames. The ideological and teacher education frames were excluded, not because they have no influence, but because they are not directly inferred from the data available.

We also used third-order instruments for the representation of the results, such as the reflection-practice integration horizon, which allowed the evolution of the teacher to be viewed over the course of the two school years that the research lasted, as well as giving an overall representation of the integration of reflection and practice.

The information was processed using the AQUAD computer program. Its application was mainly centred on coding, search options, calculation of the information unit frequency, associations in simple coding sequence formats, and the verification of linkages (Huber et al., 2001). The documents that were analyzed by means of AQUAD were the diaries, memos, minutes of the meetings, interviews, and ethnographic records. Besides the frequency calculations, the AQUAD program allowed us to obtain the linkages of the categories that appear clustered in grouped sequences of two or three. From the linkages between the codes, we obtained the core categories which stand out because of their high frequency rates, or the nucleating agents which also link positively with other categories.

Results

Analysis of reflection

The reflection category analysis was carried out from three complementary perspectives: statistical frequency analysis, content analysis, and linkage analysis. The use of the AQUAD computer program was especially helpful in coding the categories, calculating frequencies, and searching for relationships between categories in the linkage analysis. The teacher's diaries were transformed into the appropriate numbered lines of text for the previously established category coding. Other categories emerged from these sources of information during the coding process. For reasons of space, we shall only show a sample of the result of the coding. Thus the following excerpt from her second year diary, referring to laboratory practical work, shows how she introduces

open problems in her reflection (code POPR, in the analytical structure "Types of Problems"):

242 Today we did the practical
–> (242 - 248): POPR
243 A.13, this consisted of preparing a
244 solution of 2 gm of potassium
245 permanganate in 250 ml of water, for that I
246 explained to them how to use the scale to
247 weigh 2 g and how to measure the 250 ml
248 in a graduated flask. The class has been
–> (248 - 251): POPR
249 distributed into 4 groups of 4 students each
250 and they alone have weighed and measured the 2
251 g and 250 ml of water. Once the solution
252 was prepared I proposed a series of
253 questions like:
254 Which is the solute and the solvent?
255 Can the solution be made without moving the
–> (255 - 256): POPR
256 liquid?
257 Calculate the concentration in g/l and in %.
258 Why is the solution produced?
–> (258 - 258): POPR
259 What will be the concentration in a spoon
–> (259 - 260): POPR
260 of this solution? **Diary–2001/2002**

After coding, we performed a content analysis for each analytical structure or substructure according to the complexity hypothesis, so that, rather than following a merely mechanical process, we had to make judgements on the dimension that the teacher had currently reached.

A frequency analysis was a second form of analyzing the reflection. We thought it was advisable to distinguish three types of reflection according to the number of participants, what it is used for, or the type of instruments used, so that we could appropriately triangulate the sources of information. We felt that the teachers might be more or less open depending on the context of the reflection, and in the event this was indeed borne out. Table I presents the evolution of the frequency analysis for Marina in the two school years studied.

During the year 2002/03, we observed a tendency towards the practical and critical dimensions, although the most important increase in complexity towards the practical dimension occurred in the interrogative reflection, i.e., during the final interview. The introspective reflection was at a somewhat lower level than the group reflection.

Type of reflection	***Nº of Participants***	***Oriented towards***	***Analysis instruments 2002/03***	***Results for Marina 2001/02 (704 codes)***	***Results for Marina 2002/03 (662 codes)***
Introspective	One	Inquiry	Teacher's diary *(292* codes)*	Technical dim.: 87% Practical dim. 13% Critical dim.: 0%	Technical dim.: 67% Practical dim.: 31% Critical dim.: 2%
Interrogative	Two	Statement	Interview *(39 codes)*	Technical dim.: 72% Practical dim.: 28% Critical dim. 0%	Technical dim.: 20% Practical dim.: 49% Critical dim.: 31%
Grouped	More than two	Interaction	Record of meetings *(331 codes)*	Technical dim.: 59% Practical dim.: 34% Critical dim.: 7%	Technical dim.: 60% Practical dim.: 35% Critical dim.: 5%

Table I. Evolution of Marina's reflection frequencies during the two school years.

We would highlight in both school years the presence of categories of a technical nature in the teacher's reflections, as well as in an emergent form her reflections on the

students' difficulties (PDIF). Overall it can be observed that practically the same categories appear in the two school years, which shows their great stability. Also noticeable is the absence of the category associated with student control and discipline (TCON) in the second school year, which reflects its lesser weight in the teacher's reflections. However, in that second school year, there appear reflections with regard to the inflexibility of the activities (TRIG) and the reinforcement of the teacher's ideas (TREI) as emerging categories. The frequencies of the results for the two school years are summarized and discussed in Annex II.

The linkage analysis allowed us to determine the associations between two and three categories that appeared over 10 consecutive lines in a segment of text. We shall only present those corresponding to the technical dimension since they represent obstacles to professional development. Selecting the most frequent linkages in each school year, we created the diagrams shown in Figure 1 for the categories that appear with greatest frequency in the technical dimension.

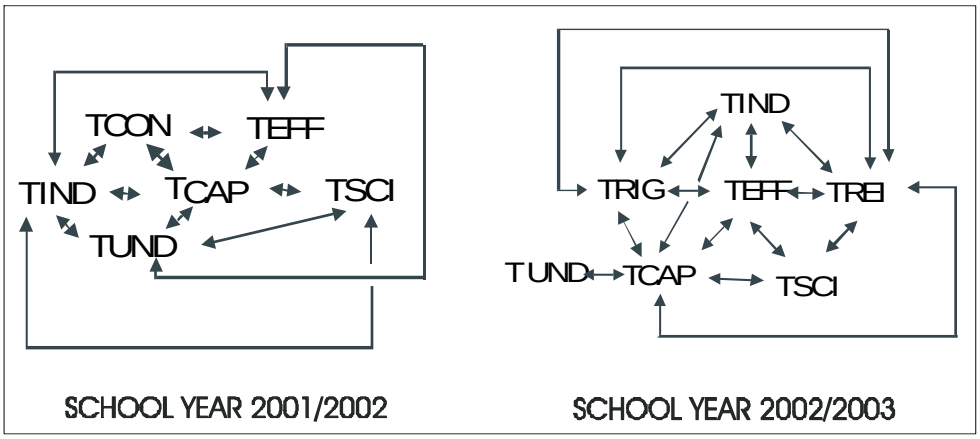


Figure 1. Most significant links between Marina's technical dimension categories.

The great stability of two nucleating agents that emerged in the two school years, acritical efficiency (TEFF) and the use of closed problems (TCAP), seems to be of particular interest since their linking capacity remains intact in time. Observing the linkages between categories in Figure 1, one can indicate that the use of closed problems of purely scientific content (TSCI), the inflexibility of the activities (TRIG), the reinforcement of the teacher's ideas (TREI), as well as the use of an acritical and technological way of thinking based on criteria of efficiency (TEFF) form the irreductible hard core of Marina's explicit theories in the technical dimension.

The classroom practice analysis

The classroom practice analysis shares the same principles of complexity and its distribution into dimensions, and the system of categories of reflection. It excludes, however, the ideological and teacher education frames. Another important difference with the reflection analysis is methodological, since the data are taken from ethnographic records and video-recordings. For the analysis of this classroom practice data, we had recourse to models, theoretical schemes, and specific taxonomies in each of the frames that we had extensively developed in other work (Vázquez-Bernal, 2006).

As examples of the analysis of practice, we shall focus on two structures (Table II): the types of problem and the sequence of activities (Vázquez-Bernal et al., 2006 & 2007b).

Types of Problems	T.D.: Use of closed-answer problems.	TCAP
	P.D.: Use of open problems.	POPR
	C.D.: Use of research problems into the social and natural environment.	CRSP
Sequence of Activities	T.D.: Rigid activities.	TRIG
	P.D.: Flexibility in the sequences of teaching.	PFLE
	C.D.: Sequences of flexible diversified activities taking the students' different rates of learning into account.	CDIV

Table II. Categories associated with the "types of problems" and "sequence of activities".

We chose these structures because, on analyzing the reflection, we observed that the use of closed-answer problems (TCAP) was one of the most frequent categories in both years. Also, in the second year, the use of closed-answer problems (TCAP) appeared strongly linked with the inflexibility of activities (TRIG). In the analysis of reflection, the use of open problems (POPR) also had a significant presence in both years, although much less than certain technical categories, and during the first year was strongly linked to technical categories.

For the analysis of classroom practice in the above categories, we followed the taxonomy of Garcia et al. (2001) and Wamba (2001), which is more explicit in classifying the activity sequence and the use of problems in the classroom. In this taxonomy, open problems (POPR) can be of three types: those which initiate processes of inquiry in the classroom (POPRa), those which question and give continuity to the process of open inquiry (POPRb), and those aimed at increasing and diversifying the students' responses (POPRc). Depending on their sociocultural content, open problems may or may not be included in the critical category. From the results of the AQUAD program analysis we created Table III, in which we compare the number and percentage of the types of problem used by the teacher in the two years of the study.

Number of problems put forward by Marina		
Type of problem	School Year 2001-2002	School Year 2002-2003
TCAP (closed)	99 (77 %)	209 (78 %)
POPR (open)	29 (23 %)	59 (21.9 %)
CRSP (open problems on the social and natural environment)	-	1 (0.1 %)

Table III. Evolution of the types of problems proposed by Marina.

As one gathers from the analysis, most of the problems put forward corresponded to random or mechanical answers of the application of some type of conceptual or procedural content studied in the unit (TCAP). The proportions between the types of problem remained practically constant in the two school years, although the number of questions and problems posed by the teacher rose notably, mainly due to the increase in student interaction and participation in the dynamics of the classroom.

The use of closed-answer problems (TCAP) predominated in both Marina's reflections and her practice during the two years, sharing space with open problems (POPR) whose purpose is to mobilize knowledge. While there was much consistency between reflection and classroom practice, both of which were in a process of becoming more complex passing from the technical to the practical dimension, it was in reflection during the second year that there was a significant increase in the percentage of open problems.

Initially, in the first year's reflection, she was inflexible in the use of formulas to solve closed problems:

> "... since they do not know how to apply the formula, or they do so by a rule of three, I tell them 'Do not do it like that, you must apply the formula for concentrations'. I think that if we give them the formula, the reason is for them to apply it." (Year 2001/2002 – TCAP)

Her attitude changes during the first year, becoming self-critical and trying to give more prominence to the pupils:

> "I did the exercise without giving them time to think and worry themselves about doing it. I think this was a mistake on my part because I'm not giving them long enough to think and solve problems and doubts on their own. In this regard, I should be more patient and act in some other way." (Year 2001/2002 – POPR)

In second year's reflection, Marina argues for the use of more open questions with the pupils' participation and, in some cases, with a more social orientation:

> "Well, it was exactly that I had told them that they should not give me rules of three, so that they would apply the formula, and perhaps they would understand better using the rules of three." (Year 2002/2003 – TCAP)

> "The problems should not be so closed." (Year 2002/2003 – POPR)

"I thought that groups of three pupils could do a mural on the 'Prestige' disaster using information from the press. At the end of the class I explained it to them, and arranged to see them in the library during the morning break to collect the information they need and begin to do the mural for one or two weeks." (Year 2002/2003 – CRSP)

"And also to employ problems of socio-environmental inquiry, I think that is important." (Year 2002/2003 – CRSP)

In the second year, there also began an incipient transition towards the critical dimension, both in reflection and in practice, reflected in her use of and concern for open problems of investigation centred on the social and natural environment.

The sequence of activities was closely related to the type of problem. The most frequently used activity sequences in Marina's practice were rigid (TRIG), using algorithmic type closed-answer problems (TCAP), as is shown in Figure 2:

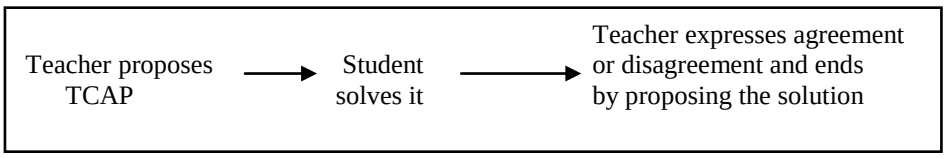


Figure 2. Technical sequence of activities (TRIG).

The following excerpt from the ethnographic record of a class in the first year (ETN2–2001) shows this kind of structure:

148 The concept of substance is introduced. The
–> (148 - 151) **(TCAP)**
149 teacher asks questions about this concept. A
150 students replies that "it is everything that
151 forms matter". The teacher gives
152 examples of substances. ETN2–2001

A variant of the above is one in which the sequence can continue with other closed-answer problems (TCAP), as reflected in Figure 3:

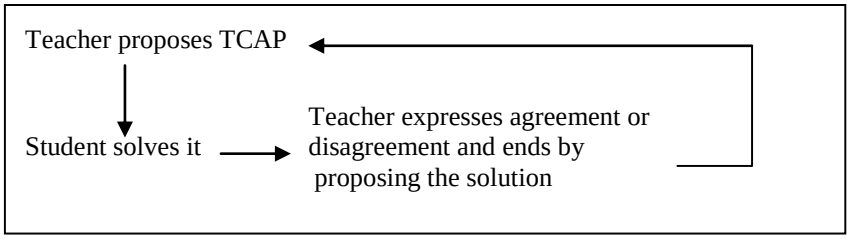


Figure 3. Sequence technical activities cyclic (TRIG).

The following excerpt from the second year reflects this kind of structure.

9.51 h Gives another example and writes on the blackboard:
10 g alcohol in 5 litres of water
Asks for the solute. Students respond. Asks how to calculate the concentration. She herself replies and says "How much should there be in 1 litre". Asks for the formula to be applied and writes on the blackboard:

$$c = \frac{10\ g}{5\ l} = 2\ g/l$$

9.52 h The teacher asks about the meaning of the solution. The students reply. She says that it could have been done

mentally. She adds that the concentration is "a way of indicating the grams of solute per litre of solution."
9.53 h Asks if it has been understood. The students seem to assent. **ETN9–2002**

It shows the teacher's interest in doing a more open and participatory activity, as was agreed in the reflection on the work group:

> "I don't give the children the option to investigate, to be wrong, to do it themselves. This indeed I'd like to change, not always to be me doing everything in class and that the pupils just receive everything done already." (Year 2001/2002- PFLE)

The flexible sequence of activities (PFLE), situated in the practical dimension, was little used in the classroom by Marina in either year, and, when it was, it was usually associated with open problems (POPR). For example, Figure 4 shows the sequence that begins with an open problem to start the activity (POPRa), the student solves it, and the teacher then questions the reply with an open problem of continuity (POPRb):

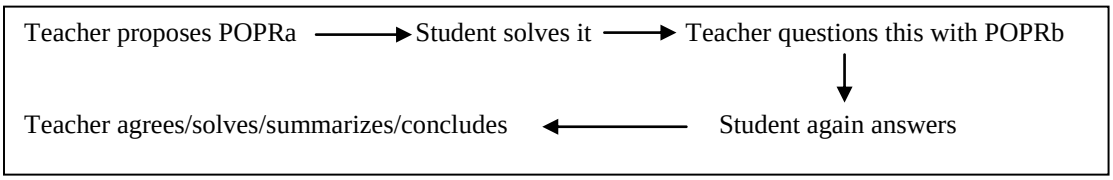
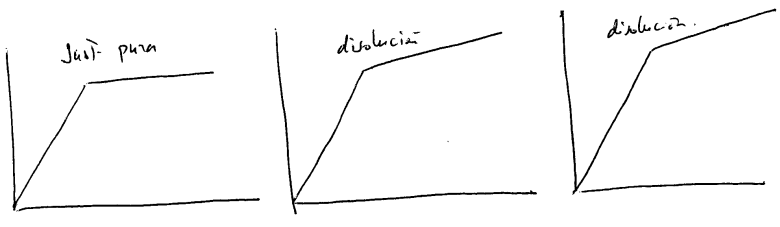


Figure 4. Practical sequence of open intervention.

The following excerpt from the second year reflects this type of structure. It shows the teacher's effort to not provide the students with an immediate answer, as she used to do in the first year. Instead she tries to prolong their reflection, an issue which, from her point of view, was of the utmost importance for her professional development:

12.43 h. Asks them to look for similarities between the temperature-time graphs (**POPRa**) for three different substances: pure substance (left), dilute salt-water solution (centre), and concentrated salt-water solution (right). Some students comment that the rise in all the graphs is to the boiling point.
12.44 h. She asks whether they agree or not (**POPRb**). The teacher draws on the graphs of the student. Another student gives a convincing answer about the differences. She says that they all keep rising, except the first graph that corresponds to a pure substance. The teacher has written on the graphs:



12.45 h. She asks the students about i t **(POPRb).** The students answer.
12.46 h. She gives the conclusions on how to differentiate pure substance and solution. The students copy it down in their notebooks. She asks if it is understood. ETN6–2002.

In the second year's reflection., Marina defends the use of more flexible activities with open problems that make the pupils think:

> "Well we could use it as a problem of extension at the end of the unit, here is this problem and let's see who can do it." (Year 2002/2003 – PFLE).

"I have also set some flexible activities, apart from those already programmed. That is, I set these activities alternating with the scheduled activities." (Year 2002/2003 – CDIV)

The sequence that would correspond to the critical dimension would consist of flexible and diversified activities suited to the students' different rates of learning (CDIV). During the first year, there was no sequence of this type. In the second year, Marina uses more open questions, and in some cases comes closer to this type of structure (Figure 5).

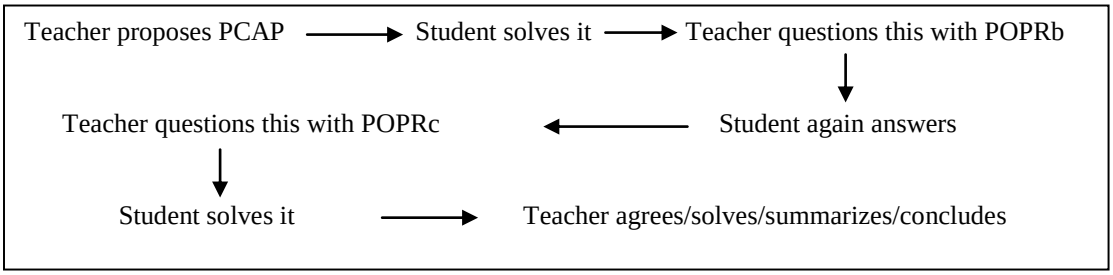


Figure 5. Sequence of open and diversified intervention.

In sum, the vast majority of the activity sequences that Marina used in classroom practice in both years were rigid (TRIG), associated with closed-answer problems (TCAP). The teacher poses these problems, and they are solved either by the students, generally as algorithmic application activities, or by the teacher expressing disagreement with the students' solution and giving her own solution. The reason for this type of practice is found in their initial teacher education, which is very much centred on the content of their discipline, and in their own many years experience as pupils themselves and then as teachers which contributes to creating powerful routines.

During the second year, Marina used some flexible activities (PFLE) related to open problems (POPR), and initiated a certain less rigid and more diversified intervention suited to the students' different rates of learning (CDIV). Basically, Marina's position is within the technical dimension because of the type of sequence that she usually employs in the classroom – rigid and closed, with little prospect that the students will diversify their responses. Nonetheless, during the second year we appreciated an increase in interventions that encouraged flexibility in the activity sequences, and a fledgling attempt to diversify those sequences, adapting them to the different rates of learning that coexist in the classroom. We therefore understand that, at this specific point, she has initiated the transition towards greater complexity of her teaching practice.

The use of problems of a closed nature, and the rigidity of her activities, constituted

the hard core of Marina's theories, and represented serious impediments to her professional development. These barriers were not overcome during the study period. Nonetheless, new expectations arose from the work group which led Marina to start using flexible activities associated with open problems. These hold enormous potential for her professional development, since they involve opening up to more complex thought and action that are open to interaction and sensitive to the multiplicity of factors that can condition the simple act of addressing a problem.

The support offered by the work group in the debates and discussions helped to overcome the teacher's initial tension and some of her routine behaviours, giving her the greater self-confidence to dare to innovate. Her final statements reflected her satisfaction as a teacher during the second year and with the changes she had made during her participation in the research.

> "Over the three years, I have seen how I have changed..."
> "... but it is that this year I have not found too many difficulties in the problems, in the past I did have many difficulties with the problems."
> "This year I felt very comfortable."
> "So I felt good, much better than other years, yes."
> (Spontaneous statements during the meetings at the end of the 2nd year)

Holistic representation of the interaction between reflection and practice

To allow an overall comparison of the reflection and practice results, we show in Figure 6 a graphical synthesis of the analysis of the two school years studied. All the categories (structures and substructures) common to Marina's reflection and classroom practice are distributed along the horizontal axis. The possible integration or non-integration between reflection (R) and practice (P) is represented by the corresponding symbol.

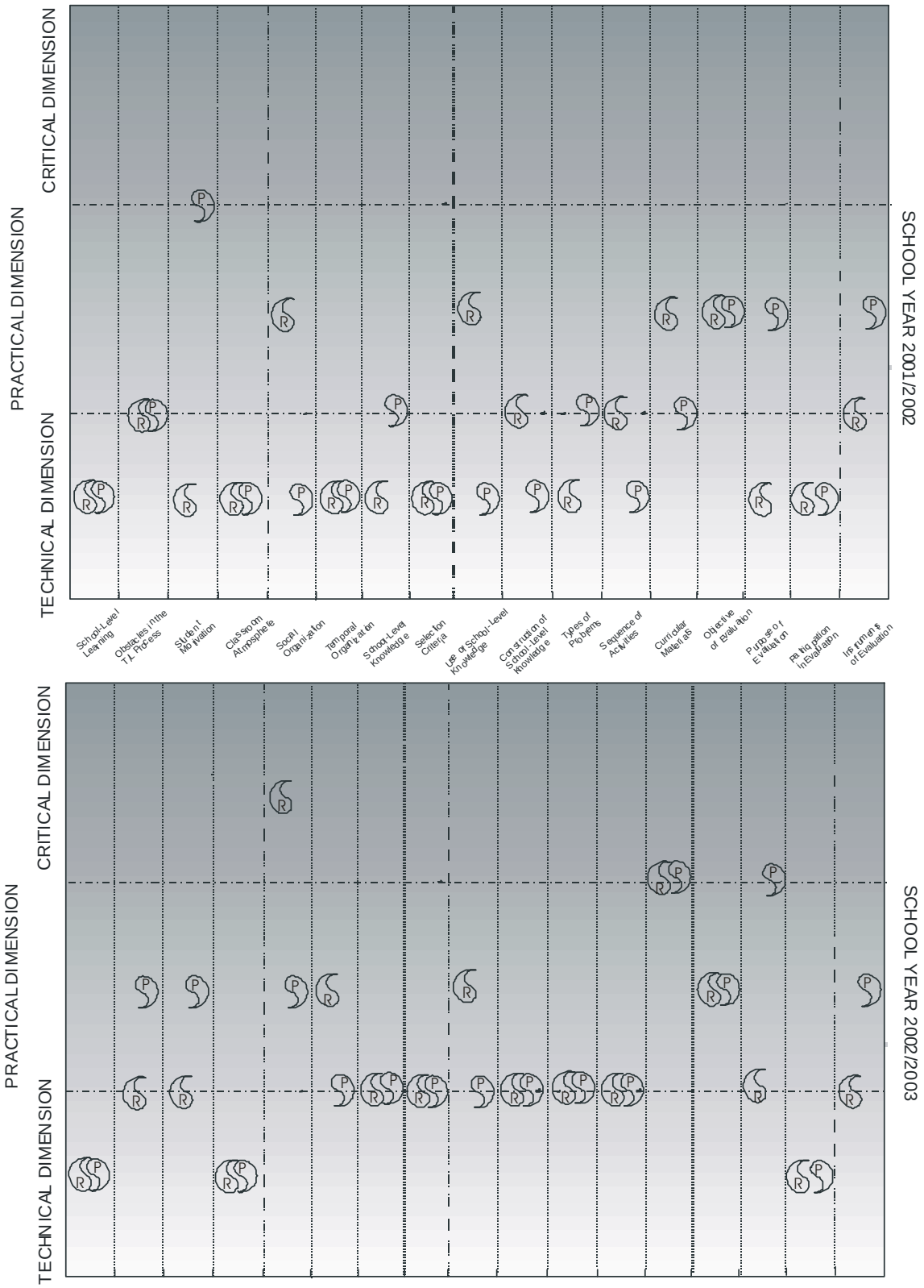


Figure 6. Marina's reflection-practice integration horizon.

The three zones corresponding to the critical, practical, and technical dimensions are located on the vertical axis, and between them there are two intermediate zones, represented by dash-dotted lines, which symbolize the transition towards the practical or

critical dimensions. In the centres of each dimension are the zones of the dimensions themselves. Qualitative criteria are also taken into account: for a category to be considered in transition between two dimensions, the frequencies in the more complex dimension must be greater than 20%.

Comparing the results between the two school years, one notes that twelve of the seventeen categories evolved towards greater complexity (Table IV). Five categories evolved in both reflection and practice, four only in practice, and three only in reflection. Only in the category of student motivation was there recession in practice between the first and the second year. Another aspect worthy of note was the immobility of three categories in the technical dimension: school-level learning, classroom atmosphere, and participation in evaluation.

▪ Obstacles in the T-L process:		Practice
▪ Motivation of the student:		Practice
▪ Social organization:	Reflection	Practice
▪ Temporal organization:	Reflection	
▪ School-level knowledge:	Reflection	
▪ Criteria for the selection of information sources:	Reflection	Practice
▪ Utility of school-level knowledge:		Practice
▪ Construction of school-level knowledge:		Practice
▪ Type of problem:	Reflection	
▪ Activity sequence:		Practice
▪ Teacher and student curricular materials:	Reflection	Practice
▪ Objective of evaluation:	Reflection	Practice

Table IV. Evolution in reflection and/or practice of different areas.

Figure 6 clearly shows that during the first year most categories were located in the technical dimension. In the second, however, most were located in the transition zone between the technical and practical dimensions.

Our results indicate that there is progress in reflection and practice, but that there exist frequent instances of lags in many areas. It therefore can not be said in a general form that any one of them is more advanced than the other. In the second school year in three areas, Marina's reflection was clearly more advanced in the process of complexity than her practice. These areas were social organization, temporal (scheduling) organization, and the use of school-level knowledge. In four areas, her practice was more complex: obstacles in the teaching-learning process, motivation of the student, purpose of evaluation, and evaluation instruments.

In sum the changes are slow and gradual and they affect some areas more than others. This is symptomatic of the complexity of the interactions that arise and of the

different constraints to which the teacher found herself subjected throughout the process.

Table V presents the degree of integration between reflection and practice in the different categories for each year. In the second year, there was an evident increase of the number of categories in which this integration had taken place.

	School Year 2001/2002	*School Year 2002/2003*
Integration reflection-practice	▪ School-level learning ▪ Obstacles in the T-L process ▪ Classroom atmosphere ▪ Temporal organization ▪ Criteria for the selection of information sources ▪ Objective of evaluation ▪ Participation in evaluation	▪ School-level learning ▪ Classroom atmosphere ▪ School-level knowledge ▪ Criteria for the selection of information sources ▪ Construction of school-level knowledge ▪ Type of problem ▪ Activity sequence ▪ Teacher and student curricular materials ▪ Objective of evaluation ▪ Participation in evaluation
Partial integration reflection-practice	▪ School-level knowledge ▪ Construction of school-level knowledge ▪ Type of problem ▪ Activity sequence ▪ Teacher and student curricular materials ▪ Evaluation instruments	▪ Obstacles in the T-L process ▪ Motivation of the student ▪ Temporal organization ▪ Utility of school-level knowledge ▪ Evaluation instruments
Lack of integration reflection-practice	▪ Motivation of the student ▪ Social organization ▪ Utility of school-level knowledge ▪ Purpose of evaluation	▪ Social organization ▪ Purpose of evaluation

Table V. Degree of integration between reflection and practice in the two years of the study.

Conclusions

We will approach the conclusions in terms of the questions that guided our study:

a) The analysis of the integration confirmed that in the second school year there existed a degree of full integration between reflection and classroom practice in 10 of the 17 areas studied. In other areas, however, there was a degree of partial integration or even an evident lack of integration between reflection and practice. This is coherent with our fundamental premise that reflection not only guides action, but is in turn guided by it in a process of mutual and convergent interaction and that a program of professional development has to take both aspects into account.

b) When the evolution of Marina's reflection is observed overall, the existence of a complex process is clearly perceived. This holistic vision shows how the teacher is in transition from the technical towards the practical dimension. The deepening nature of her reflection, above all in the terms that correspond to introspective and interrogative reflection, indicates that innovative discourse is gradually entering into her reflections and into the analysis that she carries out. The overall analysis of her classroom practice also shows a perceptible complexity from the technical towards the practical dimension. When one considers more specific or partial aspects, however, certain differences were perceived, both at the internal level of reflection and practice and at the comparative level.

In Marina's case, it will be necessary to continue paying particular attention to three aspects that remain in the technical dimension. One that is especially important is her conception of school-level learning, since previous research has shown that a fundamental factor that stimulates science teachers' change is becoming aware of the existence of the students' alternative ideas (da Silva et al., 2007; Elyon, Berger & Bagno, 2008; Hewson et al., 1999; Macedo et al., 2001). A second is the classroom atmosphere, in which is included control of the class. On occasions Marina describes herself as "the controller". Previous research has shown that the metaphors used by teachers allow one to discover the implicit referents that sustain them and that have a powerful influence on their teaching behaviour in the classroom (Mellado et al., 2006). On the other hand 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; Tobin et al., 1994). Finally, the third is participation in evaluation, since the role assigned to evaluation can reflect the teacher's pædagogical model and impact decisively on the knowledge construction process for the students (Sanmartí & Alimenti, 2004).

After two years of collaborative work (drafting teaching units, joint reflection sessions, educational readings, attendance at congresses, interviews, maintaining a diary, discussions, viewing her own and her colleagues' audiovisual material), it is clear that Marina's pædagogical model has not undergone a total change, but rather a gradual evolution with some aspects having evolved more than others. We coincide with Gunstone & Northfield (1994) when they indicate that it is seldom a case of completely

abandoning the traditional models in favour of the new, but rather one of partial acquisitions and retentions.

c) With respect to the obstacles to professional development, we would highlight that Marina conceives of learning as a process of assimilation in which the students are considered to be mere recipients of information, not as one of construction of knowledge. The intrinsic character of motivation makes her think that if the students' ideas do not progress, it is because the students are not making the necessary effort. She considers control and discipline to be indispensable in her relationship with students. There persists the pressure of time in preventing diversification of the activities and attending to different rates of learning in the classroom. In her stated conceptions of the nature of science, she showed empiricist tendencies, imbued with a certain epistemological absolutism and an accumulative vision of scientific knowledge. The acritical efficacy, inflexibility in the activities, the use of closed problems, the punishment aspect of evaluation, and setting herself at the centre of most of the classroom activities, form part of the difficult to reduce core of obstacles hindering her professional development. These obstacles are closely related to the structures that have remained in the technical dimension, making it difficult for her to evolve. These structures are strongly ingrained and consolidated in Marina by her years of professional experience.

d) Despite the limitations noted above, we believe that the action-research program has had a very positive impact on Marina's professional development. The key elements in this program were the weekly meetings during the two school years of the study and the exchange of experiences. This investigation suggests that experienced teachers' professional development programs have to be maintained over years for the improvements obtained to be consolidated individually and collectively. Otherwise the existing obstacles may make teachers return to many aspects of their initial pædagogical models. The results of our professional development program, far from meaning the end of the process, are merely the beginning of a new cycle in the action-research process, now with more solid starting data. In this new cycle, we are continuing to obtain new data that contribute to our knowledge of science teaching, but above all that stimulate and consolidate the professional development of all who participate in the research.

Final thoughts

The results that we have presented were those obtained for Marina working in the action-research program in the 2001–2002 and 2002–2003 school years. In some respects, they reflect partial and emergent professional development. We believe, however, that Marina's participation in the program has succeeded in fully involving her in her own professional development. Today Marina is teaching in a secondary school in another location. Nevertheless, she is continuing her work as a teacher-researcher on her own professional education in collaboration with university researchers (Vázquez-Bernal et al., 2010). In this new research, our aim is to link teachers' professional development with students' learning (Bañas et al., 2008). The focus is the process of the students' construction of meanings and the progression of their knowledge (Jimenez-Aleixandre & Reigosa, 2006), relating it to the teachers' pædagogical content knowledge (Abell, 2007; Gárritz & Trinidad-Velasco, 2004; Loughran et al., 2008; Nilsson, 2008; Padilla et al., 2008; Shulman, 1986).

We believe that some of the categories and analytical procedures that we used in the present study were overly complex. While this enriched the results, it hindered its independent use by teachers as tools for diagnosis and improvement. We are currently working on simplifying the analytical procedures so that, with no loss of scientific rigour, they can be used without difficulty by the participating teachers. This would also facilitate the transfer of results to initial teacher education and to novice teachers who are just starting out on their careers. These are stages in which classroom strategies and routines are formed, after which they become far more difficult to change.

Finally, the development model we propose is consistent with studies foundin the literature on effective school improvement, it provides evidence for the potential of integrative approaches, in which teacher learning is combined with innovation in curriculum and instruction, evaluation and performance feedback, school leadership development, and the management of the school’s external contacts (Scheerens, 2010).

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Annex I. Reflection Analysis Categories System (R.A.C.S.).

FRAMES	STRUCTURES	SUBSTRUC-TURES	CATEGORIES	CODES
Ideological	Ideologies in The Educational Environment		T. D.: No ideological referents exist, it being an apolitical activity.	TAPO
			P.D.: Ideology as personal option.	POPT
			C.D.: Educational administration and its pressure as political fact. Influence of the social environment. The school's role in overcoming social inequalities. History as conforming the current educational situation. The analysis of ideologies in the educational context.	CADM CENV CINQ CHIS CIDE
	Teacher-Environment Relationship		T.D.: Resistance to break with the sensation of the classroom as a black box.	TBOX
			P.D.: Teacher team work.	PTWK
			C.D.: Educational profession in continual interaction with the context.	CPRO
Educational	Teacher Education		T.D.: Teacher education as a mere accumulation of credits.	TACC
			P.D.: The personal as the starting point in the improvement of the teacher.	PPER
			C.D.: Recognition of reflection as guarantor of personal change.	CREF
	Science Teaching		T.D.: Resistance to reading pædagogical material. Insecurity in the curricular domain of the material being taught.	TRES TDOM
			P.D.: Interest in reading pædagogical material. Pædagogical content knowledge.	PREA PPCK
			C.D.: Belonging to a community of professionals in which science teaching experiences are exchanged.	CEXP
Psychological	School-Level Learning		T.D.: Role of memory as principal guarantor of learning. Assimilation as guarantor of learning.	TMEM TASS
			P.D.: Construction as guarantor of meaningful learning.	PMEA
			C.D.: Learning as social construction.	CLSC
	Obstacles in the		T.D.: Students' lack of understanding.	TUND

	Teaching-Learning Process		P.D.: Reflection about the students' difficulties.	PDIF
			C.D.: Collective inquiry into the nature of the obstacles behind the difficulties.	COBS
Contextual	Interactive Teacher-Student Relationships	Student Motivation	T.D.: Individual effort of the student as intrinsic factor. Motivation already present in the groups of students.	TIND TMTV
			P.D.: Student effort and participation as extrinsic factors.	PPAR
			C.D.: Positive discrimination towards students with special educational needs and/or social deprivation.	CDIS
		Classroom Atmosphere	T.D.: Discipline and control of the class.	TCON
			P.D.: Negotiation about the working atmosphere in the classroom.	PATM
			C.D.: Systematic use of contracts with the students to regularize classroom work.	CREG
	Social Organization		T.D.: Competitiveness as impulse to learning.	TCOM
			P.D.: Student team work.	PSWK
			C.D.: Support for the socially needy.	CSOC
	Temporal Organization		T.D.: The lack of time characterizes the form of classroom intervention.	TTIM
			P.D.: The time factor is made flexible and adapted to classroom intervention.	PADA
			C.D.: Time is dynamically adapted to the different rates of learning.	CDYN
Epistemological	School-Level Knowledge		T.D.: Scientific knowledge as fundamental knowledge of the curricular content.	TSCI
			P.D.: Reference to the daily experience of the student. Adaptation of the scientific content to the school environment.	PDLY PAPD
			C.D.: School science possesses its own epistemological status inherent to its social character.	CEPI
	Selection Criteria for the Information Sources		T.D.: Acritical efficacy and its role in improvement.	TEFF
			P.D.: Providing answers to open questions that are proposed.	PANS
			C.D.: Making decisions and acquiring commitments.	CDEC
	Use of School-Level Knowledge		T.D.: Concern to attain objectives and complete the programming.	TPRG
			P.D.: Acquisition of basic skills in solving problems	PSKI
			C.D.: The formation of citizens with critical capacity concerning advances in science and technology.	CCIT
	Construction of School-Level Knowledge		T.D.: The teacher as the sole constructor of school-level knowledge. Reinforcement of the ideas presented by the teacher.	TSOL TREI
			P.D.: Attention to the students' interests.	PINT
			C.D.: Negotiation with the students on aspects of the curriculum.	CNEG
Curricular	Types of Problems		T.D.: Use of closed-answer problems.	TCAP
			P.D.: Use of open problems.	POPR
			C.D.: Use of research problems on the social and natural environment.	CRSP
	Sequence of Activities		T.D.: Rigid activities.	TRIG
			P.D.: Flexibility in the sequences of teaching.	PFLE
			C.D.: Sequences of flexible diversified activities taking the students' different rates of learning into account.	CDIV
	Curricular Materials or Information Sources		T.D.: Use of the textbook as principal source of information.	TTEX
			P.D.: Use of different sources of information.	PSOU
			C.D.: Socially important problems.	CSIM
	Evaluation	Objective (what to evaluate)	T.D.: Objectivity of evaluation.	TOBJ
			P.D.: Subjectivity of evaluation; Evolution of the students' ideas.	PSUB PIDE
			C.D.: Acquisition of student-centred skills.	CCEN
		Purpose of Evaluation	T.D.: Sanctioned evaluation.	TSAN
			P.D.: Evaluation as summary and overview of the process.	PSUM
			C.D.: Evaluation as centred on the development of the individual as a social entity.	CDEV
		Participation in Evaluation	T.D.: The teacher as sole guarantor of the evaluation process.	TGUA
			P.D.: Participation of the student in the evaluation process.	PSTU
			C.D.: Co-evaluation carried out by teachers and students.	CCOE
		Instruments of Evaluation	T.D.: Use of the final examination.	TEXA
			P.D.: Diversity of sources for the evaluation.	PDSE
			C.D.: The students' productions based on metacognition and self-evaluation.	CMET

Annex II. Frequency analysis of the category codes

During the 2001/02 school year, the categories that appeared with greatest frequency (62) are scientific knowledge as the fundamental knowledge of the curricular content (TSCI) and the individual effort of the student as an intrinsic factor (TIND), both belonging to the technical dimension. These are followed (59) by reflection on the difficulties of the students (PDIF), in the practical dimension. Other technical categories occurred with somewhat less frequency: the use of problems with closed answers (54: TCAP), acritical efficacy and its contribution to improvement (54: TEFF), discipline and control of the class (45: TCON), and allusions to the students' lack of understanding (45: TUND) as an obstacle in the teaching-learning process. With far less frequency were found some of the practical categories: the use of different sources of information (19: PSOU), the use of open problems (9: POPR), and the evolution of the students' ideas (9: PIDE) as an

objective to evaluate. The only category of the critical dimension that appeared with a significant frequency (21) is the recognition of reflection as guarantor of teacher personal change (CREF).

During the 2002/03 school year, the category that appeared with greatest frequency (97) is scientific knowledge as the fundamental knowledge of the curricular content (TSCI), belonging to the technical dimension. This was followed by reflection on the difficulties of the students (PDIF) of the practical dimension (51). There follow at some distance other technical categories: reinforcement of the ideas presented by the teacher (41: TREI), allusions to the students' lack of understanding (39: TUND), acritical efficacy and its contribution to improvement, in which the teacher only provides information, and goes no further than just correcting mistakes (36: TEFF), the use of problems with closed answers (36: TCAP), rigidly-controlled activities (34: TRIG), and the individual effort of the student as an intrinsic factor (32: TIND). The following corresponded to practical categories: the effort and participation of the student as extrinsic factors (29: PPAR), the use of open problems (26: POPR), student team work (16: PSWK), and the acquisition of basic skills in solving problems (15: PSKI). The two categories of the critical dimension that appeared with significant frequencies, (12) and (7), are, respectively, the recognition of reflection as guarantor of teacher personal change (CREF), and the use of research problems on the social and natural environment (CRSP).