Another piece of the puzzle: the relationship between beliefs and practice in higher education organic chemistry

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An original study about beliefs, conceptions and discourse analyses of organic chemistry teachers is presented. We used Likert questionnaires and discourse analysis to examine conceptions of the nature of science, learning and teaching at university level. A case study of four female teachers with varying experience and teacher training was performed. The results show that when teachers were asked about their beliefs, they tended to express constructivist ideas, especially about the nature of science. However, in their practical discourse, during the classes, they exhibited more traditional positions. The discourse analyses then become a powerful tool which can be considered a beliefsgate to analyse conceptions.

Keywords: beliefs, conceptions, discourse analysis, organic chemistry, university teachers

Beliefs, conceptions and discourse in science classes

In 1992 Lederman wrote *"each line of research (...) is but a piece of a much larger puzzle"* (Lederman cited in Water-Adams, 2006, p. 939). In this statement he refers to research on teachers' beliefs about the nature of science. Our interest goes further. We focus on a piece of the puzzle that covers the link of beliefs and practice to the nature of science, teaching and learning in a college organic chemistry course at the first year level. To analyse the link, we present a case study about the relationship between beliefs and practice in higher education. Being a case study, it is important to stress the fact that we are not striving to work with a representative sample, but to provide exploratory and original evidence about issues that are important to science educators' researchers and trainers.

Although there is a strong tradition of research on teachers' beliefs at pre-college level, research at university level is still undeveloped. It is only in the last decade that a body of literature that examines the beliefs and practices of university teachers has begun to emerge. The majority of these works have teaching and learning as their main interest, but not the nature of science (Kane et al., 2002).

Moreover, there is some agreement about the origin of these beliefs. Teachers' beliefs and their belief systems are grounded in their personal experience. They are the product of an enculturation process, which results from their learning experiences and become richer with their teaching practice (Abell *et al*., 1998, Kagan, 1992, Mellado, 1996).

Previous research in this area has found that teachers' conceptions about the nature of science tend to follow a positivistic model linked to empiricism. Conceptions about learning and teaching are less traditional than their beliefs about the nature of science (Porlán *et al.*, 1998; Acevedo and Acevedo, 2002; Lorenzo and Rossi, 2008)

The relationship between these beliefs and teaching practice is still unclear. In some cases conceptions could act as powerful predictors of behaviour, reinforcing actions that are consistent with them. In other cases, conceptions allow inconsistent behaviours to occur in different contexts because of compartmentalization (Gess-Newsome, 1999, Lederman, 1999).

Some authors have thus suggested the existence of an increasingly complex picture regarding the link between conceptions and practice (Laplante, 1997, Watters–Adams, 2006). Other authors stated that having particular conceptions can be a necessary but not sufficient condition. The reason is that there are several variables that may affect and constrain the translation of teachers' conceptions into practice (Abd-El-Khalick and Lederman, 2000). Other authors claimed that this relationship is reciprocal since teachers' conception bases affect their lesson planning and classroom practice, and likewise, their teaching activities influence their conception bases (de Jong *et al.*, 2002).

Furthermore, it has been proposed that teachers' beliefs about the nature of science are related to teachers' beliefs about learning and teaching. These beliefs are viewed as 'nested epistemologies', and a change in teachers' conceptions about teaching and learning science may be a prerequisite for changing their beliefs about science. (Laplante, 1997, Tsay, 2002).

Both teachers' personal beliefs and practical experience jointly make up their personal pedagogical knowledge. The interplay between general pedagogical knowledge, which is derived from the research and scholarly literature, and personal pedagogical knowledge through reflection, results in context-specific pedagogical knowledge. This kind of knowledge helps to guide teachers' decisions and actions (Morine-Dershimer and Kent, 1999).

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A critical issue in our research is the methodology used to approach the problem. Researchers and teacher trainers have developed a broad array of methodologies and techniques that 'correlate' (in Kagan´s sense). Methods range from questionnaires, interviews, concept maps and pictorial representations to classroom observations (Kagan, 1992, Abd-El-Khalick and Lederman, 2000, Kane *et al*., 2002).

In the Spanish-speaking world, one of the questionnaires most frequently applied to find out about teachers' beliefs and conceptions is the "Inventory of Teachers' Pedagogical and Science Beliefs (INPECIP)". It was designed and validated by Porlán in 1989, and it has been used in subsequent investigations (Porlán *et al*., 1997; 1998; Mellado, 1998; Porlán and Martin, 2002; Ruiz *et al*., 2005; Da-Silva *et al*., 2007; Mellado, 2008).

In this survey, each statement refers to opposing models. The main characteristics of the models are:

- Traditional model: includes an empiricist–inductivist view of the nature of science. It stresses the justification of knowledge founded on observation and through an inductive scientific method. A traditional transference model of teaching prevails. Learning is viewed as the accumulation and reproduction of information.
- Constructivist model: This model of science is relativistic and context-dependent. It acknowledges the influence of psychological, social, historic and technological factors in the production of knowledge. Its view of teaching is based on the development of activities that cause meaningful and genuine learning.

Questionnaires mainly describe the espoused theory, so they are very useful tools to enquire about declarative knowledge. However, in order to explore the teachers' procedural knowledge, it is also necessary to look into the theories in use that prevail as tacit knowledge. Methods that researchers have used to describe the theories in use are direct observation, stimulated recall interviews, think aloud protocols, journal keeping, retrospective interviews and document analysis (Kane *et al*., 2002). Nonetheless, researches have not employed discourse analysis to explore implicit knowledge. Usually, speech analysis in the classroom has been used to study linguistic and structural aspects of discourse (Van Dijk and Kinstch, 1983; Sanchez *et al*., 1994; Candela, 2001).

Our research aims to describe and to understand what happens in the actual classroom, when teachers and students try to build common knowledge together (Edwards and Mercer, 1994; Coll and Onrubia, 1996). To achieve our goals, we used discourse analysis as our main research method.

Actually, we have combined two different approaches in order to explore the conceptions and beliefs of four teachers. We analyse teachers' discourse in the classroom to infer their conceptions and beliefs, which we then contrast with the same teachers' responses to a conventional questionnaire. The reason for this procedure is that when a teacher teaches, she/he shares concepts with her/his pupils, as well as values and representations of the world that she/he supports (Fourez and Mathy, 1997).

Knowledge and understanding are fundamental to professional development experiences. Teachers' trainers and researchers need to take into account and be aware of teachers' knowledge and beliefs, but not to judge them or to look for mistakes. If they are regarded as mistakes, this could sometimes hinder staff development (Mellado, 2004). Our aim is to understand teachers' knowledge and beliefs in order to analyse and reflect about them with the teachers themselves.

The first organic chemistry course in the School of Pharmacy and BioChemistry (SP&B) – University of Buenos Aires

The context is critically important in any research of teachers' practices and beliefs. Consequently, an overview of the scenario is presented here so as to facilitate the interpretation of our results and conclusions.

The classes observed are mandatory for freshmen of a first course of Organic Chemistry at the University of Buenos Aires School of Pharmacy and BioChemistry (www.ffyb.uba.ar). This course is similar to other typical introductory organic chemistry courses (Hassan *et al*., 2004). Around 1,000 students attend the course every year. They are often divided into twelve to fourteen classes that are taught simultaneously in three shifts (morning, afternoon, and evening) throughout the week. It is a weekly four-hour module. There is one teacher in charge of around eighty students and between one and three assistants help her/him with the class.

All the students have the same study guide book, follow the same syllabus and do the same final exam. The classroom is a lecture hall with fixed wooden benches. Also, there is a podium for the teacher in front of the class.

Most of the time, the faculty gives lectures that follow an expository pattern, with a high density of concepts and new technical vocabulary (Lorenzo and Rossi, in press). The teacher includes descriptions in the exposition and uses the multiple languages of science (Lemke, 2002) and multiple representations (Treagust *et al*., 2000), and controls the three ways of thinking, constituted by the chemical triangle of Johnstone (1991, 1993, 2000). The class is a completely asymmetric communicative act, where the teacher determines the way students can participate (Cazden, 1991, Cros, 2003).

Faculty members enjoy the highest social prestige among students and pre-college teachers, but they do not usually have to attend teachers' educational programmes (Campanario, 2002; Jackson, 2002; Zabalza, 2007). However, university teacher training has been gaining recognition lately. The SP&B has had a non-mandatory training programme since 1994. Still, our experience with this particular group of teachers, the SP&B staff, has made it evident that the pedagogical aspects represent a real problem for them, especially when they are asked technical didactic questions to express their ideas. Their lack of specific vocabulary about learning and teaching may explain why it takes them longer to answer the questionnaires than it does secondary school teachers (Lorenzo, results unpublished). Hence, it is necessary to develop a new strategy to explore university teachers' ideas beyond the classical surveys.

Table 1 Characteristics of the teachers

Teacher N°	Teaching experience (years)	Teacher training	Age
T1	>25	Yes	53
T2	>25	Yes	48
T3	<15	In progress	36
T4	<10	No	29

Table 2 Categories and indicators for the analysis

Belief categories	Indicators
Nature of Science	• Presence of history of science, development of science • Mentions of scientific research and validation of knowledge (role of experiments, observation, method and scientists) • Links with other courses and with everyday life • Use of the language of Chemistry • Mentions of the macroscopic level (Johnstone, 1991, 1993, 2000) • Mentions of the submicroscopic level (Johnstone, 1991, 1993, 2000)
Learning	• Students' role - Investigation of students' previous knowledge - Advice to improve learning - Teacher's reaction to students' mistakes • Encouragement to participate • Types of questions (Huertas *et al*., 2008)
Teaching	• Teacher's role • Class management and structure • Didactic strategies to present the subject

On the other hand, university teachers are usually researchers, too. So, we could expect them to hold first-hand opinions about science and its nature. Consequently, this study is likely to show differences with teachers belonging to other educational levels.

Having this context in mind, we performed a study of teachers' beliefs. First, we used discourse analysis; this was followed by a traditional survey method to assess them for subsequent comparison in order to evaluate the potential of the proposed methodology.

In the next sections, we will describe both methods, present and discuss the results, and show the most representative conclusions. Finally, we shall comment on the research implications for chemistry education.

Methodology

The sample included four female teachers of Organic Chemistry, who volunteered for the study. All of them have experience in research in Organic Synthesis. Their profiles are presented in Table 1:

The methodology involved four stages:

1. Data collection: we conducted non participant observations, recorded four classes and collected the teachers' answers to the INPECIP questionnaire simultaneously over the same period. Then, we transcribed the recorded classes into an electronic format and augmented them with the information obtained from our observations.
   In order to control the content variable, the same syllabus point was covered in the four classes observed: 'Aromatic compounds'.
2. Discourse Analysis: We proceeded inductively, using grounded theory methodology (Pandit, 1996; Glaser and Holton, 2004). First, each of us did a first reading of the transcripts. We focused on the teacher's participation in the class. Then, based on this first scrutiny, we designed a guide to analyse the main elements in a subsequent reading. The categories are described in Table 2.
   After that, we both examined the transcripts using the guide, and we discussed the results to reach an agreement. Finally, we did a comparative analysis of the four classes.
3. INPECIP questionnaire: By using this instrument, we analysed quantitatively, but not statistically (because of the small sample), the teachers' epistemological tendencies about the nature of science, learning and teaching. Based on Ruiz *et al*. (2005), Da-Silva *et al.* (2007) and Mellado (2008), we assigned the statements of the survey to a constructivist or a traditional model. We divided the premises into two groups for each category. Our approach differs from other authors' because we only place an answer in a given category when it is affirmative, not when it is negative.
4. Comparison of results: We compared the results obtained with both methodologies. First, we did a general examination of all results, and then we looked for indicators in the discourses found in the replies to the INPECIP

Table 3 Teachers´ beliefs assessed through discourse

Teacher	Nature of science	Learning	Teaching
T1	Naive realistic	Cumulative through reception	Expository, traditional
T2	Interpretative, realistic	Cumulative through reception	Expository, traditional
T3	Interpretative, realistic	Cumulative through construction	Dialogic exposition
T4	Relativistic and context-dependent	Constructivist	Dialogic exposition

Results and discussion

Discourse analysis

Discourse analysis was a useful tool to look into faculty members' implicit ideas and their theories in use. Throughout this study we could determine the various profiles for the four teachers in the sample.

We include a general profile of each teacher (Table 3) based on the categories identified in the analysis of their discourse, then the profiles are justified and finally some examples[1] are provided to illustrate the indicators for each category.

Considering the teachers on an individual basis, we could say that:

- T1 did not take any explicit position on the nature of science. However, she emphasized the role of experiments and experimental evidence. The chemist or the macroscopic level of Chemistry, are absent from her speech. She presented the subjects discussed as polished truths by employing strong technical vocabulary. Her own role in the classroom was to explain, and the students' responsibility was to study in order to reproduce the concepts taught in the right way.
- T2's conceptions were very similar to T1's, although her vision of science was diluted with several voices coming from books, as a source of true knowledge. This teacher was especially worried about the assessment results of her students.
- T3 tried to hold a dialogue with the students but without forsaking her starring place. She had a realistic point of view about science and considered that learning is the result of an accumulation of knowledge.
- T4 is the youngest teacher we studied. It is important to bear in mind that she has no teaching training. Therefore, it is very interesting to find that she was the most constructivist teacher of the sample. She included scientists, and macroscopic and submicroscopic levels in her explanations, recalled historical facts and interacted with her students as well as encouraging them to work together.

The nature of science. All the teachers explained the vocabulary and the representational systems of chemistry, and used the multiple languages of chemistry. Also, in general, they kept their explanations in the symbolic vertex of Johnstone's triangle. An exception to this could be T4.

They shared a view of the substances as realistic and anthropomorphic, referring to them as if they were alive and could make decisions by themselves. This is more prominent in the speech of T3 and T4.

T3: *"…If I have an aromatic ring which is very stable, it won't **want** to lose its aromaticity and its stability, right? It'll **want** to keep it…"*

T4: *"...Benzene has that electron cloud above and beneath, which allows it to react very easily, with **whom**? with an electrophile, **someone** who likes electrons..."*

In their discourse T1, T2 and T3 made few references to the history of science. Instead, T4 used these concepts to introduce the subject.

T4: *"...Today we're going to start studying the aromatic family, OK? Many years ago, compounds were divided in aromatic and aliphatic, because aromatic compounds were the ones that gave off an aroma..."*

T4 was also the instructor who most clearly showed the progress of science by pointing out that what we know nowadays is not the same as what we used to know a hundred years ago.

T4: *"...More than a hundred years ago, researchers realised that aromatic compounds (…), when mixed with a reagent to perform an electrophilic addition, resulted in a substitution..."*

As regards the validation of scientific knowledge, T1 assigned a very important role to experimentation, but she did not describe concrete data to support her position:

T1: *"...But what happens? Actually, in experiments, anisole is found to be much more reactive than benzene in an electrophilic aromatic substitution that is what is observed in experiments..."*

"...And, in fact, experience shows that benzene is more reactive than benzaldehyde..."

T1, T2 and T4 said that science is the result of scientific work; in addition, T2 points out that sometimes scientists do not agree on some subjects.

T2: *"...Nobody dares say whether carbocation is a methyl carbocation..."*

The connection of concepts to everyday life or to the profession was poorly explained by the teachers. However, links to other courses were made. T3 is the one who made the biggest effort in this regard:

T3: *"… Because nitric acid and sulphuric acid, and hydrochloric acid, and perchloric acid, it is true, they are strong acids when I put them in water. If I mix them with other solvents, which is what you're going to do in a lab experience called non-aqueous solvents, such as acetic acid, in the Analytical Instrumental Chemistry course, you will be able to experiment with other solvents, OK?..."*

Learning. T1, T2, and T3 tested their students' previous knowledge before proceeding with their explanations.

T2: *"...Well, today's subject is aromatic compounds. Aromatic compounds, and I suppose you all have your study guides with you, and are looking at them, reading them and checking them, OK, have particular features, what are they?*

What is the carbon chain like? Uh, linear or cyclic?..."

However, T4 did it to check if their students really knew or understood what they were saying when they answered. Besides, she introduced her explanations by asking her students about the point she would develop:

T4: *"... Well, we know what aromatic compounds are. Why are we going to study aromatic compounds today? Why did we divide compounds in different groups? In our last class we did, eh, alkenes and alkynes and in today's class we're going to see aromatics? What are we doing? Dividing each class in, what?..."*

"... Well, in compound classes. Why do we study the compound classes separately and don't we see them all together?..."

T1 and T4 advised their students to try to understand the reasons behind the point being studied, to compare and establish links with other items.

T1: *"... Compare this with alkenes..."*

"...Try to work it out, but starting from the concept of what is a positive and a negative charge. If this isn't clear enough, you'll realize immediately, because after two seconds you'll have such a mess in your heads that you'll have to go back to square one..."

T2 and T3 seem to be more worried about whether their students would be able to answer the questions correctly in future assessments than about their actual understanding:

T2: *"...You should mark the hybridisation of each of the atoms and then the type of bond that results, if it's σ or π and which are the types of atomic orbitals that made that molecular orbital, OK? Good..."*

The feedback of the four teachers to their students' mistakes varied. T1 and T2 corrected their students, T3 corrected and re-asked, while T4 asked a metacognitive question.

Although all the teachers encouraged their students to participate, in T4's class the students got the most involved. In the other classes, students only answered their teachers' questions, whereas in T4's class they exposed their knowledge, asked for explanations and presented their ways of thinking. In T1, T2 and T3's classes, students have the role of recipients of knowledge which has already been constructed by others and is transmitted by the teacher. Still, they can participate, even though in a limited way, and receive the teachers' approval.

As for the types of questions the teachers asked, again T4's class was the most challenging. This teacher asked for reasons, and stressed the process by which the problems could be solved. She used her questions as a strategic tool for her students' learning. Compared with T4, T3 asked less cognitively demanding questions in order to introduce the different points of the subject discussed. T2 and T1 made declarative knowledge questions which were even less demanding from a cognitive point of view. In T1 and T2's classes, answers to questions worked as organizers of the teachers' speech. However, there was a difference: while T1 set the questions and answered them herself, T2 waited for her students' replies to carry on with her explanation.

T1: *"...Then, what do these two structures linked with a two-headed arrow mean? These two structures together are telling me that actually those π electrons aren't located in any of the pairs of carbons considered..."*

T2: *"...Well, what are our reagents?*

Student*: An alkyl halide and a Lewis acid.*

T2: *An alkyl halide and a Lewis acid which could very well be the aluminum trichloride, and supposedly a complexation occurs between the electrons of this halide and the Lewis acid, similar to this one, only that it ends up releasing a carbocation, ok?..."*

T3: *"... What will happen to this carbocation?*

Students*: It will rearrange.*

T3: *It will rearrange into a more stable one, OK? All right? So, of those two carbocations, which is the electrophile? Which of these two carbocations is the electrophile?..."*

T4: *"... Each class of compounds has similar properties which are different from those that we discussed last class. Why do they have similar properties? And, what, then, what, what am I going to see? What is it that I'm going to analyse?*

Student: *How they react.*

T4*: Well, and to see how they react, what should I do? What should I look at?*

Student*: The functional group.*

T4*: Pardon?*

Student*: The functional group.*

T4*: Fine, the functional group, and then, what am I going to look at?*

Student*: The structure.*

T4*: Fine, the structure, I see if there are electrons, if there aren't electrons. So, what can I analyse?..."*

Teaching. Most of the time, T1, T2 and T3 were the main characters in their classes. T1 presented the new topics through her expositions by using linear causality and comparisons with *"those already seen"* (Sánchez, *et al.*, 1994); she relied on a conceptual approach with a strong authority argument, thus detaching herself from her students.

T1: *"...The fact that it´s flat implies that it has carbons whose hybridisation is sp^2 and, also, that the entire compound constitutes a closed shield of π electrons, which means that those electron pairs will have to be conjugated, pairs between them..."*

"... Notice that this is the same process we followed with aliphatic hydrocarbons..."

T2 introduced the new information with markers, then looked for links between the new and the old information, comparing them, and finally she recapitulated the information presented. Although she was the only one who answered her students' questions, sometimes she delegated her authority to the textbooks.

T2: *"… We're going to summarise the main points about electrophilic addition, and then we are going to look at the reactions, sorry, electrophilic substitution, and then we are going to look at examples of electrophilic substitution..."*

"...Well, I suppose that most textbooks are much clearer than me..."

T3 clearly structured the class using markers to change topics and recapitulated the information before introducing a new point. She stressed conceptual issues in order to solve procedural ones. She used colloquial language, which helped to avoid the creation of distance with her students.

T3: *"...Electrophile generation - how are electrophiles generated?..."*

"... I know what nitric acid is and all my life I've been told that nitric acid is - what is it?..."

The progress of T4's class was confusing at times, maybe due to the high level of students' involvement. On the other hand, T4 insisted on reaching agreements with the whole group in order to continue with her lecture. Unlike the other teachers, she used a lot of analogies to explain the most important points, self-assessed her own practice in front of her students, and admitted her own mistakes. Although she used colloquial language, she also used verbs of thinking and stressed the procedures.

T4: *"... Good. See how straight it is!* [Speaking about a reaction equation drawn on the board] *Nobody will dare tell me that it's all crooked?..."*

INPECIP questionnaire

Our findings differ from Porlán's (1998), who used the same questionnaire to assess teachers' beliefs. Unlike Porlán´s

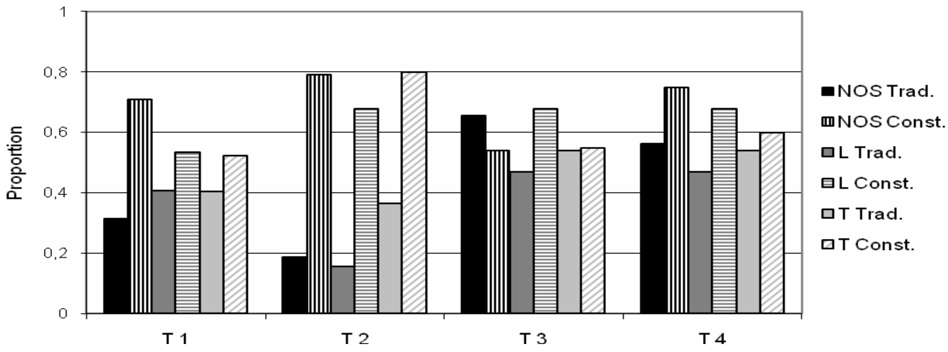

Fig. 1 Teachers' beliefs assessed through a Likert questionnaire
(NOS: Nature of Science, L: Learning, T: Teaching, Trad.: Traditional, Const.: Constructivist)

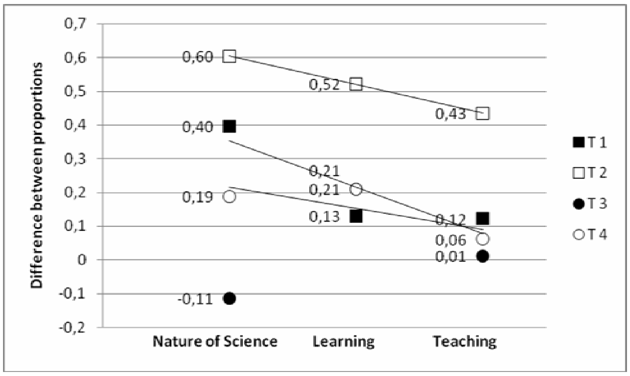

Fig. 2 Tendencies in beliefs

Table 4. Mode of teachers' answers to Likert questionnaire

Teacher	Nature of Science		Learning		Teaching	
	Const.	Trad.	Const.	Trad.	Const.	Trad.
T1	2	0	2	1	1	2
T2	3	0	3	0	3	1
T3	2	3	3	2	2	2
T4	3	3	3	3	3	3

Const.: Constructivist, Trad.: Traditional

Table 5. Consistency between methods

	Nature of Science	Learning	Teaching
T1	–	+	+
T2	–	–	–
T3	+	+	–
T4	–	–	–

+: Positive consistency; –: Negative consistency

results, our study shows that constructivist beliefs prevail over traditional ones.

The four teachers in the sample answered all the items in the questionnaire[2]. In Fig. 1, we show the proportion of the score given by individual teachers to each item, in relation to the total score for the category. Although, the four teachers had both constructivist and traditional conceptions, T2 had the most constructivist profile.

Except for T3, the other three teachers showed a more constructivist vision of the nature of science than of learning or teaching. Conceptions about teaching tended to be the most traditional aspect in all of them, including T3 (see Fig. 2).

Concerning T3, she was a special case because her responses to 29 of the total items (53) were either neutral or indecisive. She gave them a 2 point-score on a 0-4 point scale. The prevalence of answers for each category can be seen in Table 4. Consistently, in the mode analysis, T2 is the most constructivist of the sample.

After carrying out a general analysis of the data obtained through the Likert survey, we could summarise some points:

- Although all the teachers in the sample had both constructivist and traditional conceptions, T2 and T1 showed more constructivist views than T3 and T4. This difference could be due to their years of experience in teaching, and to their teacher training. On the one hand, traditional ideas are developed through the teachers' education and professional practice. On the other, nowadays constructivist ideas have spread widely mainly through teacher training programmes. Therefore, we can understand the coexistence of beliefs from both currents of thought, and the recognition of items that belong to the constructivist corpus of knowledge.
- In this work, the most traditional views were about teaching conceptions. This could be due to academic prejudices. The university sphere could constrain teachers to have more constructivist beliefs about teaching.

Comparison of results

In Table 5 we present the consistency of the two methods used to assess the teachers' beliefs. To explore this, we compared the teachers' conceptions for each of the categories, bearing in mind features of the constructivist and traditional models: If the teacher upheld the same conceptions in both studies we indicated the coincidence with a (+), if not we indicated (-).

Only in a very few cases there was uniformity between both methods and this was the case with T1 and T3. The views implied in the discourses of T2 and T4 were totally different from their responses to the questionnaire.

To perform a more detailed analysis of these cases, we contrasted the score assigned by each teacher to individual items with the same teacher's speech. As an example, we present the analysis made for T1. After that we discuss the results obtained in all the cases together.

T1

- *Nature of Science*: In the survey she agrees with the statement that scientific theories, obtained at the end of a methodologically rigorous process, are a true reflection of reality. For her, the scientific observer should not act under the influence of previous theories about the problem being studied. However, she also agrees with the statement that when observing reality, it is impossible to avoid a certain degree of distortion introduced by the observer. She adds that human thoughts are conditioned by subjective and emotional aspects. Through her discourse, we could infer the importance of observation and experimentation, but she did not underline the possibility that the scientist could introduce distortions to these observations, because she presented the subject as if topics were true.
- *Learning*: She states that conceptual errors should be corrected by explaining the correct interpretation as often as the student needs it. This statement is consistent with her behaviour in class, because the only time that a student made a mistake, she just gave her the right answer. She does not think that the starting point for scientific learning should be the students' spontaneous ideas. In consequence, she did not ask questions to check what the students already knew about the topic. She indicated that to learn a scientific concept, the student had to make a mental effort to memorize it, although in the class she advised her students to reason and not to memorise. For her, learning Organic Chemistry is a matter of effort. Consistently, this was her advice to her students. On the one hand, she asserts that students do not show that they have learnt just by answering correctly the questions that the teacher poses to them. On the other, she did not ask her students questions that could indicate their actual knowledge.
- *Teaching:* She agrees that the students should have no direct involvement in planning and assessing the activities in class. Perhaps that is why she structured the class only around her explanations. Also, accordingly, she states that science teaching based on spoken explanations of the topics does not encourage the students' rote learning of the content.

In general, when we studied the statements and compared them with their class, we found some agreements and disagreements between the espoused theories and the theories in use, too. We found that the divergences were more significant in T2 and T4's cases. However, when we considered the individual statements of the questionnaire and the discourse analysis, we could discern that T2 had the most different theories. In all the categories, her declarative beliefs were not the same as her procedural beliefs.

A probable explanation for the results obtained in the case of T2 is that she knew what the 'right' answers to questions were, but this does not necessary mean that these actually represented her views. This is true of our students' learning, and it could also be true in this case.

Conclusions

The differences between declarative and procedural knowledge could be due to constraints imposed by the context and individual inconsistencies. However, they may also be due to the way of assessing them. Predetermined verbal descriptions present in Likert-type surveys only require the recognition of statements in order to respond to them in the 'right' way. In contrast, discourse analysis appears to be a powerful tool that enables us to study teachers' beliefs as shown in their actual practice. The combination of both methodologies gives us the different features of their ideas, and consequently a more thorough, complete and accurate representation of the teachers' beliefs.

Although it is quite true that the context constrains the expression of teachers' personal ideas and beliefs, it is no less true that in this study the context was almost the same for all the teachers analysed. In our study, the four classes were following the same course, had the same rules, syllabus and textbook, the same student profiles, the same classrooms with the same wooden benches and literally, the same blackboard.

Hence, bearing in mind the individual features of each group of students and the overall contextual setting, several deep differences could be detected among the teachers. It is highly probable that those differences might be linked to individual differences, including beliefs and conceptions. These points would make an interesting area for further research. Some questions appear: Would these differences also appear with teachers from different sciences? Will there be any differences among teachers from different regions and countries? Moreover, additional investigations may extend from the case study format and adopt statistical methods that would allow for generalizations.

According to our ideas about the importance of a teacher's conceptions and beliefs in her professional development, we used surveys and discourse analysis process as meta-didactical tool. By using the proposed dual methodology we could help teachers to show them the contrast between what they say and what they do, in order to make them aware of their beliefs and conceptions. As an example, in a training course at our school in 2007, we gave university teachers the chance to analyse their own presentations in order to detect the beliefs and conceptions that appeared in their practice. Awareness of their own conceptions and beliefs allowed the teachers to reflect about their own practice. The results of this experience are still under evaluation, so in a future publication we hope to be able to describe more deeply the meta-didactical power of this strategy in teacher training.

The close connection between language and thinking is undeniable. Discourse analysis is a powerful instrument to grasp implicit beliefs and conceptions. It may be considered as a *beliefs gate,* a door into beliefs that may allow analysts to go further and deeper beyond declarative and explicit ideas.

Discourse analysis has shown remarkable implications for science education's research. Although this methodology has its difficulties and complexity, the, prospects are good. It could help us to study different aspects of science classes such as pedagogical content knowledge, symbolic representations, and chemical language, among others. Therefore, it is worth continuing to explore all the possibilities that discourse analysis still gives us.

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References and notes

[1] The translation of the teachers' and student' discourses is ours.

[2] See the full statements in Porlán *et al*., 1997 (in Spanish) or Da-Silva *et al*., 2007 (in English). However, because of the need to adapt the questionnaire to our specific context, we introduced some slight changes.

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