Emergent Theorizations in Modelling the Teaching of Two Science Teachers

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Abstract:

As the main goal of this study is to understand the teacher's thoughts and action when he/she is immersed in the activity of teaching, its purpose concerns the comprehension of the teacher's practice. With this aim we describe the procedures used to model the teaching of two teachers with respect to the topic of Plant Diversity. Starting from the consideration of theoretical constructs of script, routine and improvisation, this modelisation basically corresponds to the microanalysis of the teacher's beliefs, goals and knowledge, which are highlighted in the classroom activity.

From such a modelisation some theorisations emerge, which correspond to abstractions gained from concrete cases. They allow us to bring to the foreground strong relationships between beliefs and actions, knowledge and objectives of the teacher in action. Envisaged as conjectures and not as generalisations, these abstractions could possibly be extended to other cases, as well as tested out with new case studies raising questions over their formulation or perhaps demonstrating that the limits of their applicability do not go beyond the original cases.

Key words:

Emergent theorizations; grounded theory; interpretative filters; professional knowledge; teaching modelling; teaching science; scripts; science teaching.

Teachers' professional practice can be studied from many perspectives. It can be a source of problems and challenges for theory and teachers themselves, from the viewpoint of a reflexive professional (Schön 1987), of a professional as researcher into the curriculum (Stenhouse 1984), of action research (Elliott 1990), involved in collaborative research (Author 2 2002; 2003a, b) or practice can be analysed with the aim of improving its comprehension, through the characterisation of its elements (Krainer 1999).

It is in this sense of understanding teachers' practice that this study is oriented, as its main aim is to understand their cognition and action. For this reason the study focuses on generating conjectures (emergent theorisations) from the suppositions of the conceptualisation of Grounded Theory[1], which take account of the relations which exist between the above mentioned teacher's cognition and action.

To this end, the teaching of two teachers of natural science is modelled through a modelling instrument (MI) (Author 1 2006), which allows a cognitive analysis of their actions, particularly in the interactive stage of teaching. The *teaching models* obtained are described in function of *beliefs, goals and knowledge in action*, when the teachers approach the teaching unit *Plant Diversity*.

Theoretical framework

According to Shulman (1986a), understanding teaching implies an understanding of the thinking and action of the teacher, this being a full understanding (Clark & Peterson 1986) when these two domains are studied together, and each is examined in relation to the other.

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[1] Grounded Theory was first formulated by Barney Glaser and Anselm Strauss in 1967, quoted in Strauss and Corbin (1997, 1998).

In order to research the complexity of the phenomenon of teaching, the model of Schoenfeld (1998a, b) was taken as the starting point for considering jointly the thinking and action of the teacher, allowing the beliefs, knowledge, goals and sequence of actions implemented by the teacher to be analysed in a specific teaching context. Schoenfeld's model shows itself a powerful tool for accessing the key aspects of teaching thought and action, and allows one to understand how these aspects jointly interact. Moreover, another strength of this model is that it allows teaching to be modelled independently of the teacher's teaching style, that is to say, without linking the styles obtained to particular pedagogical models.

However, the process of modelling must necessarily be limited so as to be operative, and there is no direct account taken by it of other elements of the process of teaching and learning, such as knowledge, beliefs and expectations of the students, or the context.

Taking into consideration previous studies by Author 2 (1994); Aguirre and Speer (1999); Schoenfeld (1998b) and Thompson (1984), primacy is given in the process of modelling teaching to *beliefs in action*, on the assumption that: (i) these provide an account for why a particular sequence of actions is implemented by the teacher; (ii) they are considered as playing an active part prior to determining classroom performance, and (iii) they are assigned by the researchers, in general, without taking any kind of statement from the subject. In the same way as beliefs, the teacher's knowledge set is another key aspect to be borne in mind when taking account of practice, as attested by Sherin et al. (2000). This knowledge set is keenly activated in the teaching context, depending on what is happening at any particular moment, as well as on the teacher's planning (Schoenfeld 1998b). In this respect, it is important to bear in mind that not all the teacher's knowledge is in play at any particular moment (Verloop et al. 2001).

Bearing in mind the Shulman's (1986b, 1987) studies on teachers' organisation of knowledge, as well as those of Schoenfeld (1998b) and Schoenfeld et al. (2000) in the same vein, primacy is given to *knowledge in action*, relative to subject matter (SM), pedagogical content knowledge (PCK) and general pedagogical knowledge (GPK). In this study, knowledge of subject is limited to that related to *Plant Diversity*, the teaching unit being tackled by the participating teachers.

To GPK, which Shulman (1986b) considers a special kind of professional understanding on the part of the teacher, Schoenfeld (1998b) adds classroom management, teaching strategies, and teacher's knowledge of teaching, learning and students. Certain of these strategies correspond to interactive elicitation, Socratic elicitation, unplanned excursion and mini-presentation, including monologue (Schoenfeld et al. 2000).

PCK corresponds to the most useful means of representing said content, the most powerful analogies, metaphors, illustrations, examples, explanations and demonstrations, that is, the means of representing and formulating content matter so as to make it understandable to others (Shulman 1986b; 1987). Schoenfeld (1998b) also includes curricular material, knowledge of strategies and representations of issues particular to teaching.

In the same way as beliefs and knowledge, the teacher also presents a wide range of goals when teaching, which are to be found at different levels of activation. Aguirre and Speer (1999) demonstrate that goals in action can be pre-existing or emerge when the lesson is in progress, and that there are even goals that, due to their tacit nature, can be hidden during the planning of the lesson (Porlán 1993). In the process of modelling teaching primacy is also given to *goals in action*, that is, to those goals that are: (i) achieved through the action sequences set up by the teacher; (ii) inferred from the action to the detriment of the range of goals that the teacher could present; (iii) closely linked to specific moments in the lesson; (iv) centred on the teacher. For example, in this system of modelling, the student-centred goal "Understand the concept of photosynthesis" can be turned into a teacher-centred goal "Explain the subject content photosynthesis by talking to the students".

With respect to the actions and/or sequence of actions put into effect by the teacher, consistent with the prior activation of the cognitions or cognitive constructs (Artzt & Thomas-Armour 2002) mentioned above, it is acknowledged that these actions can studied through the application of theoretical frameworks denominated routines, scripts and improvisations (Schank & Abelson 1977; Shoenfeld 2000; Sherin et al. 2000). The recognition of these theoretical frameworks is important as they enable various features of the teacher's thinking to be captured, integrating aspects of cognition and the specific teaching context, and they go beyond the observable behaviour of the teacher in that they include the meanings attributed to said behaviour (Erickson 1989).

In the process of modelling teaching proposed by Author 1 (2006), a routine corresponds to the basic structure of a standardised and routinised sequence of actions or also a single routinised action in a specific context (Schank & Abelson 1977; Shoenfeld 2000; Sherin et al. 2000), and is independent of content.

Scripts [2] correspond to a sequence of actions in a specific context, likewise standardised and routinised, which are conceptually marked (in this case in relation to *Plant Diversity*). According to Schank and Abelson (1995) people have at their disposal thousands of very personal scripts which they put to daily use, reducing the need to think. That this is so depends on detailed knowledge of the specifics of routine situations, with the result that the mental processing required to negotiate frequently experienced events is minimised (Schank & Abelson 1977).

In addition to routines and scripts, many teacher interventions can be understood as improvisations. As the very name suggests, improvisation corresponds to an action which

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[2] The theoretical entity script comes from the work of Schank and Abelson (1977 and 1995) in the area of cognitive and social psychology, and has also been used by Luger (2002) and other authors in the sphere of artificial intelligence.

arises in response to an event which happens unexpectedly in the classroom (Schoenfeld 2000).

Methodology

The present study is located within the interpretive paradigm proposed by Latorre et al. (1977), so as to emphasise the understanding and interpretation of the educational circumstances from the meanings attributed to the people involved in educational contexts, and to study their beliefs, intentions, motivations and other aspects of their knowledge.

Within this paradigm, Bogdan and Biklen (1994) also assume that the researcher plays an important role in the interpretation which is undertaken. In the process of research there are two relevant elements on the part of the researchers: *theoretical sensitivity* (Strauss & Corbin 1994), resulting from their experiences at the personal and research levels, and *phenomenological sensitivity* (Van Maanen 1988 in Geelan 2003), which concerns how the researcher perceives events through his and others' experiences.

According to Lincoln and Guba (1985), the kind of research to be undertaken is a naturalistic study, whereby the real phenomena must not be isolated from their context and should occur in the scene or natural context of the object of study.

As it is not intended that the results of the research should establish general patterns or universal abstractions, but rather concrete and specific universalities (Erickson 1989) which lead to a deeper understanding of teacher cognition and action, a case study methodology was chosen, with the principal objective of understanding the case in the question (Stake 1998).

It is, then, via a case study that the modelling of the two participants' teaching is undertaken, and it is this that reveals the detailed features of the beliefs, goals, knowledge and actions of each at every moment in the process of teaching.

The very course of the case study determines which data collection tools are to be used, based on an understanding of these grounded in the bibliographic review, it being a question of an emergent design. Lincoln and Guba (1985) note that an emergent design employed within the naturalistic research paradigm arises logically from the data instead of being constructed a priori, as it is inconceivable that the design should be fully known beforehand, but rather it should emerge as a function of the interaction between the subjects and the phenomenon, it being highly unforeseeable before the phenomenon actually occurs.

The participating teachers in this study (CM and SS) work in primary schools in the Algarve, Portugal. At the time of the study both were in their first year of teaching and gave the topic *Plant Diversity* to the fifth year of Natural Sciences.

Beginning teachers were chosen as informants as, in agreement with Mellado (2003), the first years of teaching are considered to be when one's teaching routines and strategies become fixed. Being party to these early days took on a special relevance for us as teacher trainers.

The study took the form of a selective or theoretically motivated sample in preference to a random or representative one, because, as Lincoln and Guba (1985) argue, this type of sample increases the range of the data that are present (with respect to transferability) and, as Patton (1900) argues, a selective sample provides the study with richer data.

In the research process information was gathered primarily in the interactive stage of the teaching, and it was decided that video recordings of lessons should predominantly be used. In accordance with Rochelle (2000), this is the tool that was considered to best preserve the interactive aspects such as conversation and gesture, and no less importantly, video recordings provided benefits at the analytic stage, allowing multiple viewings of a particular event, and facilitating the micro-analysis of the phenomenon of teaching. The video recording was supplemented by a microphone fixed onto the teacher to record the sounds that were not picked up on the video.

Data collection was completed with the gathering of documents relating to each teacher's practice, the researchers' field notes, photographs, interviews, lesson images[3], and the research notebook.

The analysis of the information corresponds to the modelling of the teaching, and starts with the process of transcribing, line-by-line (according to Schoenfeld 1998a, b), the information relating to the twelve and fifteen lessons given by the teachers CM and SS respectively (see figure 1).

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[3] Lesson images are teacher projections of what they expect to occur in the lesson (Zimmerlin & Nelson 2000), and is not to be confused with planning. Teachers should not be forced to follow an outline prepared in advance when they come to describe what they expect to happen (for example, the difficulties they foresee and how they anticipate dealing with them), as imposing such a requirement might bring about changes in their habits, as Peterson and Clark (1978) show.

T: Of all the plants that you know we can divide them into two big groups. What are they?
T: If you went and had a look at plants, are all the plants the same? No.
T: A big difference that you see in plants?
T: A difference. Say it, say it.
S: Flower.
T: Flowering and non-flowering. So, there are flowering and non-flowering plants.
T: The T draws a flow-chart on the board, flowering and non-flowering plants and their constituent parts.
T: These flowering plants are made up of...? We can say on the outside.
S: The root.
T: The root. What else?
S: The stalk.
T: The root, the stalk, the leaf and the flower, which then produces the..?
S: Fruit.
T: The fruit.
T: On the other hand, the non-flowering plants, what are they made up of?
S: Just with a trunk.
T: With a trunk. What did I say the stalk was called?
T: By a root, with...? It has to feed. By the stalk, and by..?
S: The leaf.
T: So, let's open our notebooks, please.
S: What for?
T: To decorate the board; to copy, Levy.
S: I'm copying.
T: OK, right you are.
T: T waits for the students to copy the flow-chart into their notebooks.
T: Has everybody copied it?

Figure 1. Transcription of an excerpt from CM's first lesson (T denotes teacher and S any student).

The second stage of the modelling process corresponds to dividing each lesson up into episodes and sub-episodes (modelling instrument MI, see figure 2). Each episode corresponds to an action sequence occurring in the lesson, underlying which there is a coherent set of actions originated by the teacher. According to Schoenfeld et al. (2000), the action sequence is the basic unit of the teaching model, and must fulfil two fundamental requirements: (i) be phenomenologically coherent, that is to say, exhibit continuity in the discussion of a particular topic or class activity; and (ii) correspond directly to a state of heightened activation of one or more of the objectives assigned to the teacher by the researchers. The action sequence, according to Schoenfeld (1998b), is characterised by the triggering and terminating event(s) of the respective action sequence of, the teacher's belief(s), goal(s) or objective(s), and knowledge, the type of episode and part of the lesson image.

[3.1.] Name of episode (or specification of improvisation where this is the case) (lines)
Triggering Event(s):
Event (if occurring) which triggers the action sequence.
Belief(s):
Identification of beliefs underlying the action sequence.
Goal(s):
Identification of goal underlying the action sequence.
Episode type:
Routine, script or improvisation.
Knowledge:
Identification of teacher's knowledge required to implement the action sequence.
PCK - Pedagogical Content Knowledge
GPK - General Pedagogical Knowledge
SM - Subject Matter
Part of lesson image:
Part of lesson image relating to the episode.
Terminating Event(s):
Event (if occurring), which triggers the termination of the action sequence.

[3.1.1.] Teacher action(s) (lines).

Interactive elicitation or Socratic elicitation or unplanned excursion (lines)
Monologue or mini-presentation (lines)
Specific content

[3.1.2.] Teacher action(s) (lines).

Interactive elicitation or Socratic elicitation or unplanned excursion (lines)
Monologue or mini-presentation (lines)
Specific content

Figure 2. Schematic representation of the process of forming a model of teaching, at the stage of characterising each episode and respective sub-episodes.

The modelling instrument used in this study (MI) derives from an adaptation of Schoenfeld's (1998a, b; 2000) model, with incorporations of aspects from other studies: Schank and Abelson (1977); Shulman (1986b; 1987); Santos (1991); Porlán (1993); Author 2 (1998); Aguirre and Speer (1999); Sherin et al. (2000); Schoenfeld et al. (2000); Zimmerlin and Nelson (2000); Verloop et al. (2001); Climent (2002); Cañal (2004). As noted in the theoretical framework, these adaptations concern the notions of scripts, routines and improvisations on the one hand, and GPK, PCK and SM, as well as goals on the other. The adaptation relating to beliefs is outlined below, given that this has meant the application of an analytical tool for them.

With the goal of facilitating the identification of the beliefs of the Natural Science teachers at primary level, an analytical tool was used, in the form of a theoretical scheme, adapted from that used by Climent (2002) in respect of primary teachers' thought processes. As Climent's (2002) instrument does not consider aspects relating to evaluation, and as it is based on the instrument used in Author 2 (1998) besides, the corresponding part of this latter's analytical tool was added with respect to evaluation. The descriptors of the analytical instrument for the beliefs of the Natural Science primary teachers are organised into the following categories: teacher's methodology, school science, learning, student role, primary teacher role, and evaluation. The distinctions between the four tendencies maintained by the above mentioned writers are also equally respected: the Traditional Tendency (TR), the Technological Tendency (TE), the Spontaneous Tendency (S), and the Investigative Tendency (I). However, when it comes to analysing the teachers' beliefs, the assigning of descriptors has an orientating purpose, given that it was never of interest to this study to locate the teachers in one or other pedagogical tendencies (even the term pedagogical tendency itself underlines the difficulty of encountering individuals that fit neatly into a specific model, Porlán 1989).

This will be dealt with in greater detail in figure 3 below through an example of the application of the MI.

Analysis and discussion of findings

The result of the modelling process described above is the creation of the teaching models of the teachers CM and SS. These models characterise the beliefs, goals and knowledge in action, jointly interacting, as can be seen in the example presented in figure 3, which summarises the analysis of the ninth episode of CM's first lesson. CM begins by talking to the students about plant morphology ([1.9.1.]), via Socratic elicitation which the teacher directs and which in some way had been planned by him. Following this, CM draws a flow-chart on the blackboard representing the same theme ([1.9.2.]), which establishes that plants are comprised of root, stalk, leaf, flower and fruit. And last in this sequence of three actions, the teacher waits while the students copy the chart into their notebooks ([1.9.3.]).

As is evident, the sequence of actions forms a script in that the sequence it comprises is standardised, routinised, and conceptually marked, linked to the contents of the topic Plant Diversity relating to plant morphology (root, stalk, leaf, flower and fruit).

The triggering and terminating events establish the boundaries of this action sequence. The triggering event corresponds to the teacher's posing of the question: "*Are the pants that you've seen outside all the same*?" The terminating event corresponds to the moment when the teacher is satisfied that all the students have had sufficient time to copy the flow-chart into their notebooks.

The image of CM's first lesson helps to confirm that his primary goal (emanating from this sequence) is to organise the subject content relating to plant morphology, using a flow-chart. In order to draw up the flow-chart and to organise the respective contents, CM has to understand the role of both the flow-chart and of Socratic elicitation.

Likewise, from the action sequence which CM sets up, it can be noted that the teacher seems to be conditioned by three beliefs: (i) the teacher organises the subject exclusively towards the acquisition of concepts; (ii) the interaction between teacher and student is not balanced, there being a stronger flow in the direction of teacher to student than vice versa, and (iii) the teacher organises the subject content to be learned, which he transmits via an exposition, using organisational and explanatory strategies which aim to be engaging.

[1.9.] *Organisation of subject content*– Plant morphology using a flow-chart (387-415) **Triggering event:** The teacher asks whether all the plants observed outside were the same. **Beliefs:** (TR7)[4] The subject is oriented exclusively to the acquisition of concepts. (TR/TE15)[4] The student interacts with the subject and T, the latter acting as mediator between the former and S. The interaction between the teacher and student is not equal, there being a stronger flow in the direction teacher-student than vice versa. (TE25-28)[4] The teacher organises the subject content to be learnt, which are transmitted via exposition, using organisational and expository strategies aimed at engaging the students. **Goal:** To organise the subject content – Plant Morphology, making use of a flow-chart. **Knowledge:** General Pedagogical Knowledge (GPK) – The role of the flow-chart and Socratic elicitation in organising the subject content. **Episode type:** Script **Part of lesson image:** The topic of Plant Morphology forms part of the lesson image. **Terminating Event:** The teacher considers that all the students have had sufficient time to copy the flow-chart into their notebooks.	[1.9.1.] The teacher talks with the students about the content of the flow-chart – Plant Morphology (387-408) Socratic elicitation (397-408) Specific content: Plant morphology – root, stalk, leaf, flower and fruit. [1.9.2.] The teacher draws a flow-chart representing the subject content on the board (409-413) Specific content: Plant morphology – root, stalk, leaf, flower and fruit. [1.9.3.] The teacher waits for the students to copy the flow-chart into their notebooks (414-415)

Figure 3. Detailed characterisation of the script *"Organisation of subject content – Plant morphology, using a flow-chart"* relating to the ninth episode of CM's first lesson (corresponding to the excerpt in figure 1).

It is not being claimed that the teacher CM's belief in directing the subject exclusively towards the acquisition of concepts produces the respective action sequence, but rather that the resultant relation was observed. It is necessary to be aware that it is impossible to apply simple mechanisms of cause and effect to the complex phenomenon that is education. However, examining and taking note of certain strong relations is an important contribution when it comes to understanding such phenomena.

Following the same procedure for characterising the script referred to previously (the above-mentioned episode), a full analysis was completed of all the episodes from all of CM's

[4] Descriptor 7 indicating the traditional pedagogical tendency (TR). TE indicates technological tendency.

and SS's lessons over roughly three and a half months. Table 1 shows the episodes relating to three specific subject contents from CM and SS, as an example.

Table 1

Episodes involving CM and SS relating to three areas of specific subject content on the topic of Plant Diversity

Teacher CM **Episodes**	**Specific contents of Natural Sciences**	**Teacher SS** **Episodes**
	Plants	
[1.2.] Review of subject content	Animate and inanimate entities	
[1.3.] Elaboration of subject content by means of a drawing activity	Plants as animate entities and examples	[1.2.] Interactive exposition of subject content involving correction of homework
	Diversity	
	Definition of diversity and examples involving flowering plants	[1.1.] Interactive exposition of subject content [2.3.] Subject content review [2.7.] Subject content review, involving correction of homework
	Plant morphology	
[1.4.] Interactive exposition of subject content [1.9.] Organisation of subject content, using flow-chart [2.5.] Review of subject content, using an overhead transparency [3.6.] [4.2.] [5.2.] Review of subject content [6.6.] Evaluation of subject content by means of examination	Plant morphology – root, stalk, leaf, flower and fruit	[1.3.] Interactive exposition of subject content, involving correction of homework [1.14.] Interactive exposition of subject content [1.18.] Review of subject content, using reading from textbook [2.4.] Review of subject content [2.8.] Review of subject content involving correction of homework [2.10.] Review of subject content, using a real plant as an example [2.17.] Memorisation of subject content involving a collection activity in the fieldtrip [8.2.] Evaluation of subject content by means of oral questions [10.3.] [10.5.] [11.10.] Memorisation of subject content involving activities with plants [12.4.] Evaluation of subject content by means of the students' coursework [14.3.] [14.5.] [14.6.] Evaluation of subject content by means of an examination

Table 1 allows differences and similarities between CM and SS to be appreciated. Both make use of scripts to tackle certain subject contents, although these might vary. For example, tackling the subject contents included in *Plants*, whilst CM makes use of two scripts, one for revising material and the other for working on a topic by means of a drawing activity, SS makes use of a script corresponding to interactive exposition for homework correction.

From this joint analysis of the cases of CM and SS there emerges a set of regularities with respect to their action sequences, and these can be abstracted into *Action Structures*.

Due to the fact that this study is based on the interpretative paradigm and adheres to the basic premises of Grounded Theory (Strauss & Corbin 1994), these abstractions result from the progressive application of interpretative "filters" taken from said models, and enable a deeper understanding of the relations that exist between the teachers' cognitions and actions, to be seen in the phenomenon of teaching.

From the teaching models of the teachers CM and SS a total of thirty-eight action structures are obtained. The numbering of these structures is organised so as to show that some are more specific instances of other, fuller ones. For example, the action structure 5.5. *Memorising the subject content, using classwork on plants* is a variation of the action structure 5. *Memorising information*. The action structure 5.5. corresponds to the action and cognition sequence set out in figure 4.

Action sequence:

[T explains the work to be done with plants relating to subject content] → [T helps the groups of students to complete the work]

Cognitions:

Beliefs:
(TE4) Manipulatives are used sparingly for consolidation, explanation or for bridging theory and practice.
(TE11) Learning is still conceived of as memory-based, with an internal organisation following the logical structure of the subject.
(TE14) It is important that students be able to make their understanding of the subject content explicit (by verbalisation, so that the teacher can check that the desired learning is taking place). The articulation of what has been learned, in the students' own words, shows the result of the learning.
(S16)[5] The ideal form of grouping to encourage learning is groupwork with its corresponding discussions.
Goal:
To propose the memorisation of subject content to the students, using work on plants.
Knowledge:
Pedagogical Content Knowledge (PCK) – The role of work on plants in the memorisation of the respective subject content.

Figure 4. Action sequence (composed of action sequence and cognitions) relating to the memorisation of subject content using classwork on plants.

As the relationships between the teacher's cognitions and actions are extremely complex and resist a hierarchical organisation, their representation is better suited to cognitive maps, following Miles and Huberman (1994). By way of example, the cognitive map corresponding to the action structure 5.5. is illustrated in figure 5.

[5] S indicates spontaneous tendency.

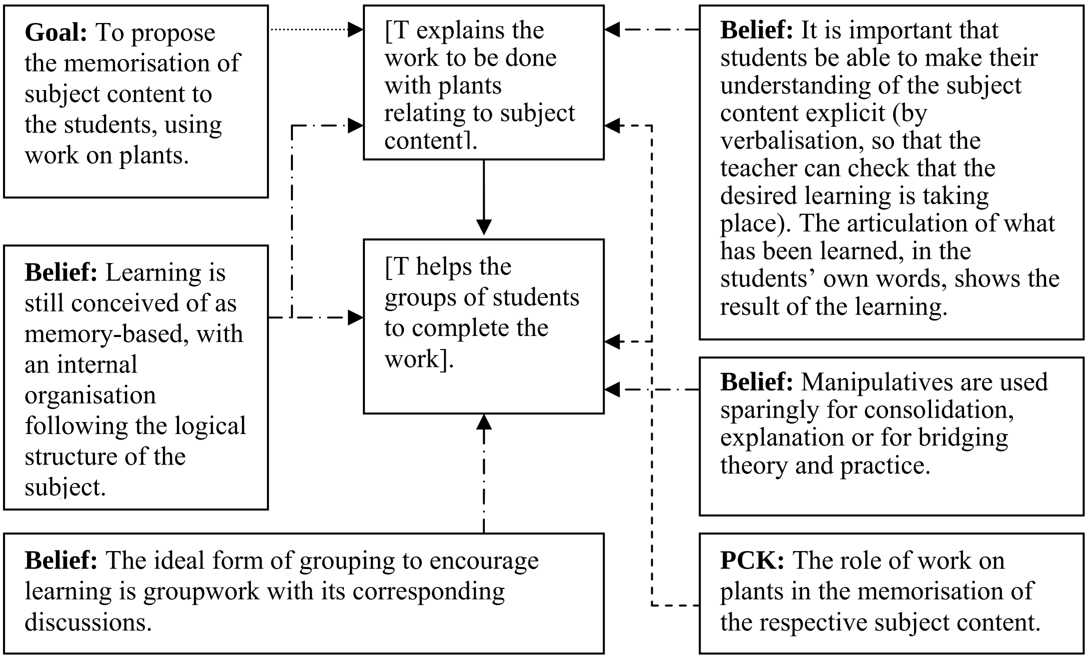

Figure 5. Cognitive map of action structure 5.5. Memorising subject content, using classwork on plants.

The function of these maps is not to offer further information, but rather to clarify existing information. Basically, they aim to transform the list of variables participating in the process, considered individually as action structures, into a complex representation of reality which is focussed on the teacher's practice.

The results have also been organised in the form of a relational network between the teacher's beliefs and actions, as illustrated in figure 6. Here, it can be seen that a set of two beliefs ('The ideal form of grouping to encourage learning is groupwork with its corresponding discussions'; and 'Manipulatives' are used sparingly for consolidation, explanation or for bridging theory and practice') conditions the action [Teacher helps the groups of students to complete the work.].

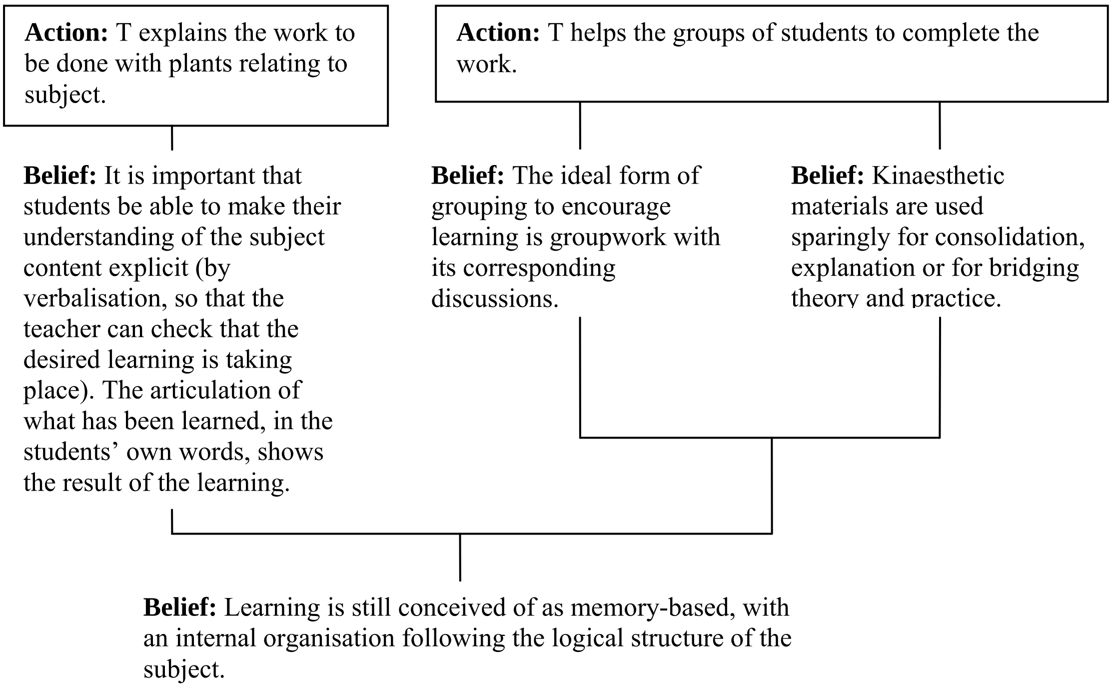

Figure 6. Diagram showing relations between teacher's beliefs and actions, in the action structure 5.5. Memorisation of information, using work on plants.

Within this same structure the diagram in figure 7 can also be considered, which provides a visual representation of how the teacher's knowledge of the role of the tasks with plants in memorising the subject content information conditions the goal of suggesting that the students memorise the respective information.

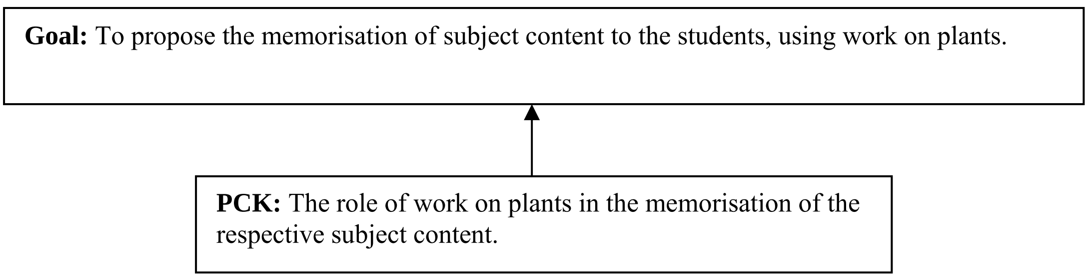

Figure 7. Diagram representing the relation between knowledge (Pedagogical Content Knowledge) and teacher's goal, in the action structure 5.5.

From an application of all the interpretative *filters* used throughout the study, strong relations are established between beliefs and sequences of actions (or unitary action) and the teacher's knowledge and goals, such as those seen in the case of the action structure 5.5. These are summarised in table 2.

Table 2

Strong relations between beliefs and actions, goals and knowledge, for action structure 5.5.

5.5. Memorising subject content by means of tasks involving plants	
Action sequence: [T explains the work to be done with plants relating to subject] - [T helps the groups of students to complete the work]	**Belief:** Learning is still conceived of as memory-based, with an internal organisation following the logical structure of the subject.
Action: [T explains the work to be done with plants relating to subject]	**Belief:** It is important that students be able to make their understanding of the subject content explicit (by verbalisation, so that the teacher can check that the desired learning is taking place). The articulation of what has been learned, in the students' own words, shows the result of the learning.
Action: [T helps the groups of students to complete the work]	**Belief:** the ideal form of grouping to encourage learning is groupwork with its corresponding discussions. **Belief**: Manipulatives are used sparingly for consolidation, explanation or for bridging theory and practice.
Goal: To propose the memorisation of subject content to the students, using work on plants.	**PCK:** The role of work on plants in the memorisation of the respective subject content.

In the same way, table 3 summarises the relations found in the case of action structure 7.1, corresponding to script 1.9 mentioned above.

Table 3

Strong relations between beliefs and actions, goals and knowledge, for action structure 7.1.

7.1. Organisation of subject content by means of a flow-chart	
Action sequence: [T draws a flow-chart representing subject content on board] - [T waits for the students to copy the flow-chart into their notebooks] - [T talks with the students about the content of the flow-chart]	**Belief:** T organises the subject content to be learnt, which are transmitted via exposition, using organisational/expository strategies aimed at engaging Sts.
Action: [T draws a flow-chart representing subject content on board]	**Belief:** S interacts with the subject and T, the latter acting as mediator between the former and S. The interaction between T and S is not equal, there being a stronger flow in the direction T>S than vice versa.
Action: [T waits for the students to copy the flow-chart into their notebooks]	**Belief:** The subject is oriented exclusively towards the acquisition of concepts.
Goal: To organise subject content using a flow-chart.	**GPK:** The role of the flow-chart, interactive elicitation and Socratic elicitation and mini-presentation in organising the subject content.

Table 4 presents various examples from the total of 31 (action structures) observed in the study, which are in some way representative of the diversity of events within the classroom.

Table 4

Strong relations between beliefs and actions, goals and knowledge, for various action structures.

1.1. Interactive exposition of subject content by means of reading the textbook	
Action sequence: [T instructs students to read relevant subject in textbook] - [T talks with the Sts about the subject] - [T clarifies and amplifies subject content]	**Belief:** The T presents the subject content developing it from elicitation rather than offering it in its entirety, using presentation strategies for support.
Action: [T instructs students to read relevant subject in textbook]	**Belief:** The chief source of information for the student is the teacher and textbook.
Actions: [T clarifies and amplifies subject content]	**Belief:** The S interacts with subject and T, who acts as mediator between this and S. The resulting interaction is not equal, with a greater flow in the direction of T>St than vice versa.
Goal: Exposition of subject content, questioning students, reading textbook passage.	**PCK:** The role of gesture, analogy, exemplification, illustration and explanation in the presentation of the subject. **GPK:** The role of interactive elicitation and unplanned excursion, monologue, mini-presentation and reading from textbook in the presentation of the subject.
6.1. Content development, employing an activity involving the recording of observations about plants, in the fieldtrip	
Action sequence: [T explains the activity involving recording observations] - [T establishes Sts groups] - [T waits for Sts to complete the activity involving recording observations and encourages group work]	**Belief:** Terminal and functional goals are aimed for, with greater emphasis placed on local procedural goals (examples are taken from concrete items, without opening up the possibility of resources beyond these concrete issues).
Action: [T explains the activity involving recording observations]	**Belief:** Manipulatives are used sparingly for consolidation, explanation or for bridging theory and practice.
Action: [T establishes Sts groups]	**Belief:** The grouping which best fosters learning is groupwork with its corresponding interaction.
Actions: [T waits for Sts to complete the activity involving recording observations and encourages group work]	**Belief:** While learning can begin with the observation of an inductive process (this, in fact, is the way the T usually presents subject content, building it up gradually), true learning must depend on a deductive process.
Goal: Develop the content, employing an activity involving the recording of observations about plants, in the fieldtrip.	**PCK:** The role of the activity involving recording observations about plants in the fieldtrip in the development of topic content. **GPK:** The role of interactive elicitation in the development of topic content.
8.1. Establishing previous knowledge of topic via a drawing activity	
Action sequence: [T instructs the Sts to do a drawing activity on the topic of study] - [T waits for Sts to draw]	**Belief:** The initial S diagnostic is based exclusively on the topic content which have supposedly already been taught.
Goal: Establish Sts' prior knowledge via a drawing activity.	**PCK:** The role of the drawing and the labelling in establishing prior knowledge of the topic. **GPK:** The role of interactive elicitation drawing activity in establishing prior knowledge of the topic.
9.1. Evaluating subject content by means of examination	
Action sequence: [T reads and explains subject content exam questions] - [T waits for Sts to finish exam individually]	**Belief:** T considers evaluation an activity which is required at the end of each of the sections into which S learning is divided, with the sole aim of measuring learning outcomes.
Action: [T waits for Sts to finish exam individually]	**Belief:** T aims to measure the S ability to retain information in the short term, valuing the mechanical application of this.
Goal: To evaluate subject content by means of examination	**GPK:** The role of the exam in evaluating subject content.

These relations constitute variables (understood as facets or aspects, and not as mathematical-statistical items) to be taken into account in understanding the enterprise of teaching.

Conclusions

The approach taken here, especially the application of the modelling instrument (profiled throughout the research), has shown itself to be useful when it comes to undertaking the modelling of the teachers CM and SS's teaching, as it has allowed a detailed analysis to be made of both teachers' actions and sequences of actions and of the beliefs, goals and knowledge underlying their actions.

The fact that this study follows the interpretative paradigm and is based on the premises of grounded theory allows interpretative "filters" to be progressively applied to the models of CM and SS's teaching, in turn a deeper understanding of the relations between the teachers' thought processes and their actions manifested in the phenomenon of teaching. In particular, the great importance of grounded theory (Strauss & Corbin 1994) can be seen in the possibilities that it makes available for the researchers to develop their own theorisations on the phenomenon they aim to understand from a more complex perspective of the problem. In this sense, in addition to making connections between the thought processes and action involved in the teaching process, grounded theory enables the development, during the process of understanding, of certain theorisations of especial interest to future projects in professional development.

It is believed (Author 1 2006) that if educational research is to contribute significant results within the interpretative paradigm, it must attempt to obtain conceptualisations from its studies, and this is basically what has been shown in this article. The emergent theorisations from the case studies of CM and SS correspond to abstractions, similar to conjectures, which, without being understood as generalisations, could possibly be extended to other cases, and the theorisations might be tested out, with new case studies bringing up questions over their formulation or perhaps demonstrating the limits of their applicability do not go beyond the original cases.

The teachers participating in this study were not required to make a commitment to professional development, as a result of which the contents of the study coincide with the teachers' own thinking. Nevertheless, the interests of the research also go beyond cataloguing associations established between the teacher's cognitions and actions, in order to reach models that can offer subsequent advances in studies into professional development.

Much research into science teaching aims to develop a basic knowledge of classroom practice to be reformulated, where possible, into recommendations for initial and continuing training of teachers. In like fashion, the results of the research presented here can become the source of recommendations for teacher training.

On the one hand, the mentoring of science teachers undertaken by a trainer could come to help him or her learn to model their own teaching, independently of their personal style. Producing a model of teaching could be achieved via the modelling instrument (MI) proposed in this study, providing the teacher with the opportunity to access aspects of their thinking and action when they are involved in the act of teaching.

Being aware of the various aspects of their thinking, such as the beliefs, goals and knowledge which underlie their classroom performance, is vitally important when it comes to reflecting on their practice, that is, improving the understanding of their teaching style (an understanding which, as has been made clear throughout this study, is not bound to any association or similarity with predetermined or favoured pedagogical tendencies).

Such an improvement in understanding one's teaching, and consequently one's professional development, needs to be translated into a conscious reconstruction of one's available scripts, so that they become increasingly varied, flexible and complex, and hence, paradoxically, less routine, combining their feature of functional activation with a certain element of standardisation, albeit open to reformulation.

The teacher's professional development can also lead to the creation of specific new action sequences which are more coherent with their desired practice (for example, sometimes a teacher may profess a certain belief with respect to learning, say, or to evaluation, but not have managed to act upon them).

On the other hand, teacher trainers have an important role to play in putting teachers in contact with each other so that they have the opportunity to compare their action structures. This comparing amongst peers is crucial for teachers to become aware of the multiplicity of approaches to classroom practice. At the very least, incorporating new elements into one's practice demands constant questioning and analysis.

In the initial training, where teacher-trainees have yet to have experience of teaching practice as educational professionals, trainers can also help them to clarify their inherent thoughts about the process of teaching sciences. Sometimes, it is suggested that the trainer employs a case method (Serrano 1994) to analyse and discuss the most significant or critical elements of the case in question with respect to the significance they hold for education. In this way, the trainer raises the students' awareness of their scripts, albeit experienced at school as students or in other experiences outside school.

For example, the teacher CM uses a flow-chart to organise the subject content because he had seen this done as the son of a primary teacher, as can be seen in the statement he makes in the final information exchange:

“*In fact, regarding the way to organise the information I use flow charts for almost all the subjects, because when I was a student I learned to do it as a way of making things easier. Perhaps I picked it up from my mother (a primary teacher), who gave me a lot of help in my first few years at school and set me to structuring everything I learned this way*.”

Teacher trainers can also help teachers or trainees to recognise that a particular action sequence can become too rigid in teaching science and that a particular cognition/action can even act as an obstacle to improving one’s teaching and consequently to one’s professional development. For example, some teachers’ difficulty in translating particular areas of knowledge into appropriate scripts means that some scripts, such as those relating to memorising information relating to classwork on plants, tend towards exercises of an illustrative nature or which reinforce the classroom-based study, to the detriment of motivating and investigative fieldwork (Morcillo et al. 1998), and this represents an obstacle to the teachers’ own preferences.

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