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RESEARCH REPORT
Concept teaching and learning

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SPANISH PROSPECTIVE TEACHERS' INITIAL IDEAS ABOUT TEACHING CHEMICAL CHANGE

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ABSTRACT: We describe and analyse the initial ideas of a sample of 24 Spanish prospective teachers about teaching the concept of chemical change to 13-14 year old pupils. The participants, working in groups, elaborated proposals to teach this concept. A content analysis of these proposals showed that: a) a great part of the content was organized in a linear sequence; b) within a diversity of methods there predominated closed sequences of laboratory observation activities aimed at allowing the pupils to infer the concepts for themselves, but without taking their pre-existing conceptions on chemical change into account; and c) evaluation was seen as a check that the pupils had acquired the knowledge that the teacher had established beforehand. Finally, we discuss some of the implications of the conceptions detected for initial teacher education. [*Chem. Educ. Res. Pract. Eur.*: 2001, *2*, 265-283]

KEY WORDS: *initial teacher education; teachers' conceptions; teaching chemical change*

INTRODUCTION

In recent years, research into what teachers (both practising and those in their phase of initial teacher education) think about science and its teaching/learning has produced a notable amount of data (Aguirre, Haggerty & Linder, 1990; Brickhouse, 1990; Cronin-Jones, 1991; Gallagher, 1991; Hollon, Roth & Anderson, 1991; Lederman, 1992; Prawat, 1992); Guilbert & Meloche, 1993; Abell & Smith, 1994; Aguirre & Haggerty, 1995; Gustafson & Rowell, 1995; Hewson, Kerby & Cook, 1995; Kouladis & Ogborn, 1995; Hashweh, 1996; Southerland & Gess-Newsome, 1999). Our own studies (Porlán, 1989; Martín del Pozo,1994; Porlán and Martín del Pozo,1996; Porlán, Rivero and Martín del Pozo,1998) coincide in showing that, together with a diversity of conceptions, there are what we might consider to be majority tendencies: an empiricist and positivist view of scientific knowledge, and a traditional conception of teaching/learning as the transmission/reception of knowledge.

None of these studies refer to a specific conceptual field, and we agree with Shulman (1986; 1992) and others (Orlandi,1991; Lederman, Gess-Newsome & Latz, 1994; Driel, Verloop & de Vos, 1998) when they call for these investigations to also address specific content of the school curriculum. In this line of research we may differentiate between:

a) Studies of prospective teachers' conceptions of the material being taught (Kruger and Summers, 1988, 1989; Kruger, Palacio and Summers, 1992; Martín del Pozo, 1994, 2001; Jong, Acampo and Verdonk, 1995; Haidar, 1997). These studies show there to exist serious deficiencies in the knowledge of basic chemical concepts, comparable to those found in Secondary Education level pupils (Holding, 1985; Andersson, 1986; Brigss and Holding, 1986; Stavridou, 1990; Hesse and Anderson, 1992; Solsona, 1997).

b) Studies of prospective teachers' pedagogical content knowledge (Martín del Pozo, 1994; Jong, 1996, 1997; Driel, Verloop and Vos, 1998; Jong et al, 1999). These have been fewer in number due, amongst other reasons, to the number of components associated with this class of knowledge. The components studied by Jong (1997) for example, in comparing the pedagogical content knowledge of experienced and prospective teachers about teaching combustion, included the curriculum, the pupils' conceptions, teaching methodology, and evaluation.

The present study is of the latter type. The aim is to describe and analyze the initial ideas of a small sample of prospective teachers about teaching chemical change. In particular, the following questions are posed:

- In their proposal for teaching chemical change, what general principles of teaching and learning do the prospective teachers include? Since it was to be expected that they would make some kind of general considerations about teaching and learning, we shall try to detect these general principles in their proposal for teaching chemical change.
- What aspects characterize the knowledge of chemical change that the prospective teachers intend to teach?
- Which aspects characterize the educational methodology with which the prospective teachers propose to teach chemical change?
- What and how do the prospective teachers intend to evaluate, as expressed in their proposals for teaching chemical change?

DESIGN OF THE STUDY

Sample

The sample consisted of 24 prospective science teachers (20 women and 4 men, mean age 22 years) who were taking the course "Chemistry and its Teaching" during their third (and last) year of teacher education, before beginning a period of practice teaching in state schools. This course was part of the official initial teacher education program of the Universidad Complutense of Madrid towards certification for teaching 6-14 year old pupils. One of the present authors was in charge of the course.

Data collection

The context in which the data were gathered was the normal situation in this course. Specifically, the data were collected during an initial activity aimed at elaborating a proposal to teach chemical change to 13-14 year olds. In initial teacher education, the elaboration of proposals to teach specific topics of the pupils' curriculum is one of the most important professional skills for the prospective teachers to learn. It is also a good opportunity for the teacher educator to detect their initial ideas about what they intend to teach and evaluate, and how they are thinking of going about it. We chose chemical change as the topic for the present study. In the activity sessions, the prospective teachers arranged themselves into six working groups of four, according to their own preferences. It should be noted that, while they elaborated their proposals in groups, we are here not interested in studying the group planning process (social interactions, negotiation of meanings, etc.). In no way does this mean that we do not value this aspect of professional knowledge, but just that, on this occasion the focus of our work was to analyse the content of their proposals.

Written plans for teaching a certain topic have been used for some time as a source of information in studying how teachers plan their teaching (Broeckmans, 1983; Clark and Peterson, 1986; Sánchez and Valcárcel, 1999). We here used them to study the content of prospective teachers' ideas about the teaching they are planning, not the elements or organization of their planning, nor the planning process.

To elaborate their proposals, the groups used any documentation that they wished and organized it according to criteria that the group itself decided on. The intervention of the course instructor was limited, in so far as the data of the present study are concerned, to sitting in on the group discussions, providing any documentation requested, and ensuring that the task was completed within the timetable agreed on beforehand. No orientation was given concerning the elements or the content of the proposal. The only indication given was that the beginning, development, and end of the planned teaching should be clearly set out in the proposal.

This initial teacher education activity was developed over six sessions (a total of eight hours), without counting the outside time that the groups used. As we indicated above, the final proposals correspond to what the groups are capable of doing at the beginning of the course. I.e., what we expected to detect are the prospective teachers' initial ideas when they come to confront this task.

Data analysis

Taking into account that we were working with few subjects (24), our treatment of the data from the written output allowed us to make only a qualitative analysis of the content. According to Goetz & LeCompte (1984), we may in general consider this to be a systematic means of manipulating the data and constructs inferred from the collected information. The most generalized type of content analysis is categorial analysis (Bardin, 1977), which may be applied to both verbal and written output of individuals or groups. The main stages in the analysis proposed by Bardin, adapted to our purposes, may be summarized as follows:

- Divide the text up into record units
- Sort these units into the pre-set dimensions and categories.
- The units are transformed into standard propositions, using a procedure of contrast with other collaborators in the study. The propositions are information units which leave the meaning unaltered, but do not coincide lexically or grammatically with the group's textual sentences.
- Infer hypothetical constructs which bin different propositions into a given category.

As orientation for the categorial analysis of the curricular proposals of the six groups, we drew up a category system as a function of the problems that were to be approached in the study (Table 1). The dimensions and categories considered were as follows:

- General principles, which refer to all those manifestations of a general nature which do not pertain to any given content or activity. Two categories were established for the analysis: principles relating to teaching and principles relating to learning.
- The content of school-level knowledge about chemical change. This was analyzed according to three categories: the level of formulation, amplitude and diversity, and conceptual organization.

TABLE 1. *Category system used in the study of the prospective teachers' conceptions about teaching of chemical change.*

CATEGORY SYSTEM	
DIMENSIONS	CATEGORIES
A. General principles.	A.1. Principles relating to teaching. A.2. Principles relating to learning.
B. Content of school-level knowledge of chemical change.	B.1. Level of formulation. B.2. Conceptual diversity and amplitude. B.3. Conceptual organization.
C. Methodology for teaching chemical change.	C.1. Role of the students' conceptions. C.2. Characterization of activities. C.3. Teacher-pupil interaction.
D. Evaluation.	D.1. Why to evaluate. D.2. What to evaluate. D.3. How to evaluate.

- The methodology for teaching chemical change. Given that this occupied the greatest part of the information contained in each group's proposal, we opted for a presentation of the record units, propositions, and constructs referring to this dimension as organized into a temporal sequence of activities: activities to start off the lessons with (initiation activities), activities to continue with the teaching/learning process (development activities) and activities proposed to end the lesson with (finalization activities).

The record units in this case were very unequal (from a single sentence to paragraphs containing a great number of sentences). The common criterion that was established was to consider as a record unit all of the information referring to a given activity (what the aim is, the material used, what the pupils do, what the teacher does, ...). The diversity is a result of the prospective teachers developing unequally the activities that they propose. The categories established for the analysis of this dimension were:

- Role of the pupils' conceptions in the teaching/learning process.
- Characterization of the activities, i.e., what is the meaning of the activity and around what is it organized, with particular attention paid to how empirical referents are used.
- The interaction that is established between teacher and pupils.

For the analysis of the evaluation, three habitual categories were chosen: goal, content, and instruments. To orient the process of inferring the constructs, we took into account the different models of the teaching/learning of science (traditional, technical, spontaneist, and constructivist) which have been detected by other workers in studies of teachers' conceptions (Hollon and Anderson, 1987; Smith and Neale, 1991; Gallagher, 1993),

TABLE 2. *Dimensions and categories used in the study according to different teaching models.*

MODELS	DIMENSIONS			
	GENERAL PRINCIPLES	SCHOOL-LEVEL CONTENT	METHODOLOGY	EVALUATION
TRADI-TIONAL	Teaching based on the verbal transmission of pre-prepared knowledge. Learning by reception of knowledge.	The content that is to be taught is a simplified and dogmatic version of the discipline's (conceptual) content.	Teaching is to be by verbal transmission from the teacher, following the textbook as complement.	Evaluation is the item-by-item verification of the pupils' conceptual learning by means of written tests (examinations).
TECH-NICAL	Teaching based on the exhaustive scheduling of goals and activities. Learning by assimilation of knowledge.	The content that is to be taught is an adaptation of the discipline's content, which takes the discipline's methodological and conceptual structure into account.	Teaching is to be by applying an empiricist version of the scientific method which is translated into a closed sequence of activities as a function of the programmed goals.	Evaluation is a process tending to measure the degree of attainment of the proposed goals by contrasting an initial diagnosis of the pupils' prior knowledge with a final diagnosis.
SPONTA-NEIST	Teaching based on pupil's discovery. Spontaneous learning in contact with reality (ingenuous empiricism).	No content is programmed. It coincides with the "scientific" knowledge that the pupils "discover" by observing and experimenting with reality.	Teaching is to be by an open set of activities as a function of the pupils' interests.	Evaluation is a mechanism of pupil participation for decision-taking concerning the dynamics of the classroom.
CON-STRU-CTIVIST	Teaching based on pupils' own investigation. Learning by construction of knowledge.	The content that is to be taught comes from the integration of the discipline's content and more everyday knowledge, represented in this case by the students'conceptions.	Teaching is to be by investigating relevant problems in the school context, with the pupils' ideas being a continual referent in the activities.	Evaluation is a continual process of adjustment between the real evolution of the pupils' conceptions and the hypothesis of the progression of school knowledge.

as well as in our own previous work (Porlán, 1989; 1993; Martín del Pozo, 1994; Porlán, Rivero and Martín del Pozo,1997; 1998; Porlán and Rivero,1998). In particular, we took into account how each of these models conceives the teaching/learning of science, school-level content, teaching methodology, and evaluation (Table 2).

PRESENTATION AND ANALYSIS OF THE RESULTS

In the following, we shall present the results of our analysis of the content of each of the dimensions that were studied to describe the prospective teachers' curricular conceptions in the conceptual field of chemical change.

A. The general principles of teaching and learning

The general principles of teaching that the groups manifested (Table 3) were based on active group work methods and on laboratory observation and experimentation activities. The teacher's role was more or less as a guide.

With respect to learning, groups 3, 5, and 6 agreed that the condition for learning to be meaningful is that the pupils' ideas should be given consideration. In their proposals, however, there was no activity which takes those ideas into account and attempts to change them. It was noteworthy that the other three groups (1, 2, 4) made no explicit reference to their conception of learning. Group 2, however, was the only one whose proposal was based on the pupils' prior ideas.

In sum, while their general declarations about teaching did seem to have an influence on the final proposal, this was not so for learning.

B. The content of school-level knowledge about chemical change

1. With respect to the level of formulation of the concept of chemical change that it is intended to teach, we would emphasize that:

Only half of the groups explicitly formulate the concept of chemical change that they expect the 13-14-year-old pupils to manage to learn. These were formulations at the macroscopic level, in terms of a change in identity of the initial substances rather than of conservation (of the elements), in contrast with physical changes. The specific formulations were the following:

> GROUP 2: "They must realize that in physical changes the nature of the substance does not vary (although its appearance does); while in chemical changes the nature changes."
> GROUP 4: "The children will have to come to the conclusion that the new substance which has been formed has characteristics which are different from the initial substances."
> GROUP 5: "If the initial state is different from the final state, it is chemical change. If there is a change of state but not of substance it is physical change."
> One can see that Group 5 uses the term "state" ("estado" in the original Spanish) to refer both to physical states (solid, liquid, and gas) and to the identity of the reactants (initial state) and the products (final state). They may thereby be limiting physical changes to changes of state, thus increasing the difficulty they usually have in differentiating between the two types of change.

If we compare these data with the level of formulation that these same prospective teachers present in an educational activity that is unrelated to teaching (Martín del Pozo, 1994), we observe that the idea of chemical change that they intend to teach is situated at the same level (Groups 4 and 5) or at a level of less complexity (Group 2) than that which they have or recall spontaneously:

TABLE 3. *Hypothetical constructs concerning general principles.*

GENERAL PRINCIPLES	
RELATING TO TEACHING	RELATING TO LEARNING
GROUP 1 - The teacher must guide laboratory activities using a script of practicals for the pupils to follow. - In the classroom, the pupils should above all work in groups.	GROUP 1 Not indicated.
GROUP 2 - The teacher proposes the activities and explains and clarifies concepts. - The pupils test their hypotheses in groups and draw conclusions.	GROUP 2 Not indicated.
GROUP 3 - The teacher must program the content and activities to be carried out. - The teacher must motivate the pupils. - The methodological sequence is based on activities of discovery (observation and experiment), explanations from the teacher, and carrying out application exercises. - An active methodology is based on the teacher's role as facilitator (orienting and motivating) of the pupils' investigations, which are based on their prior knowledge. - Pupils are to work in groups or individually according to the type of activity being carried out. - Laboratory activities are based on observation and experiment. -The directed-discovery teaching methodology enables the pupils to learn.	GROUP 3 - Learning is meaningful if a relationship is made between the pupils' prior knowledge and the new knowledge.
GROUP 4 Not indicated.	GROUP 4 Not indicated.
GROUP 5 - The pupils carry out group activities to describe, explain, and draw conclusions from the experiments.	GROUP 5 - A constructivist conception of learning is based on taking the pupils' prior knowledge into consideration.
GROUP 6 - The contact with reality and laboratory activities are important for learning concepts. - An active methodology is based on the pupils' laboratory work.	GROUP 6 - Pupils learn by means of their own observations. - Meaningful learning takes into account the pupils' prior knowledge.

GROUP 2: "These are the changes or transformations that take place when two or more substances come into contact. What really undergoes change are the internal components of the material."
GROUP 4: "It is the set of transformations that take place in certain substances (the reactants) giving rise to different substances (products). Energy is involved in it [the transformation]."
GROUP 5: "It is the process by which two or more elements or compounds interact among themselves giving rise to a new element or compound which is different from the initial ones, with the absorption or release of energy."

2. With respect to the amplitude and conceptual diversity of the content that they intended to teach, we can say that (Table 4):

- The amplitude of the knowledge that the groups aimed to teach covered up to 45 different content items. In particular, they proposed 35 concepts, 4 laws or principles (e.g., the principle of conservation of mass), and 6 aspects which, while not strictly conceptual, were proposed by five out of the six groups (e.g., critical evaluation of chemical reactions that occur around us). The representativity was low, however, since no concept was proposed by all the groups, only two (element and chemical equation) by five of the six groups, and 21 concepts were proposed by only one group. The mean was 13 content items per proposal. Group 3 proposed most items (18) and group 4 fewest (8).
  In sum, the amplitude was large, but the representativity of the content was low.
- With respect to the diversity of the content, there were items related to the structure and composition of matter at both the macroscopic and microscopic levels (only proposed by group 6). There were also specific concepts related to different types of chemical reactions (combustion, oxidation-reduction, and acid-base), and with quantitative, dynamic, and energy aspects of chemical changes. Also worthy of note was that almost all the groups included items related to other laboratory work issues, or to the risks and uses of chemical reactions. This content is not usually found in the textbooks consulted by the groups. None of the groups referred to all the aspects related to chemical change.

3. The groups organized their proposed content into a linear sequence similar to that in all the textbooks that they consulted. This means that the concepts appear one after the other with no relationship between them. Only in the case of group 3 did we detect a somewhat different conceptual organization. They used what they themselves called a "conceptual map". The concepts were organized according to quantitative, kinetic, and energy aspects. Not all the concepts that the group proposed to teach appeared in this map, however. Substance, element, and compound, which will play a structuring role when it comes to defining chemical changes, were notable absences. Also, nowhere did they indicate the relationships that exist between concepts (see Figure 1).

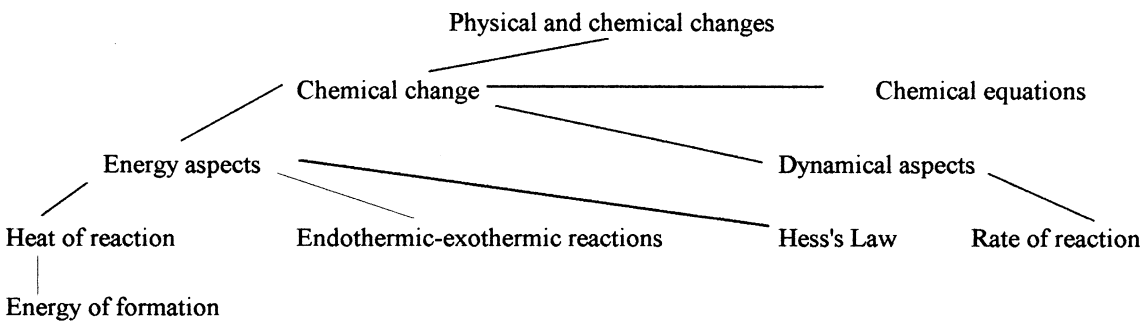

FIGURE 1. *The conceptual map drawn by group 3.*

TABLE 4. *Network of the conceptual diversity about chemical change proposed by each group. In parentheses is the number identifying each group.*

ORGANIZERS		
Composition and structure of matter	Microscopic level	Atom (6) Molecule (6) Ionic bond (6) Covalent bond (6) Formulation (4, 6) Periodic Table (6)
	Macroscopic level	Substance (1, 3, 4) Element (1, 3, 4, 5, 6) Compound (1, 3) Metals and non-metals (5, 6) Mixtures (2, 3, 5) Solutions (2, 3, 4, 5)
Transformations of matter	Chemical change	Oxidation (1, 2, 6) Combustion (1, 2) Acid-base (1, 2) Reduction (2) Reactants and products (1, 2, 3, 5) Classification (4, 6)
		Physical and chemical changes (1, 3, 5)
	Physical changes	Changes of state (2, 3, 5) Changes of form (2) Dilatation (2)
Quantitative aspects		Chemical equations, balance (1, 3, 4, 5, 6) Mole (5) Avogadro's Law or Principle (5, 6) Molar volume (5) Mass conservation (3, 5) Gram atom (5)
Energy aspects		Changes of energy (4, 5, 6) Endothermic-exothermic reactions (2, 3) Principle of conservation of energy (6) Energy of formation (3) Heat of reaction (3) Hess's Law (3)
Dynamical aspects		Rate of reaction (2, 3, 6) Catalysts (3)
Aspects relating to other issues		Dangers and usefulness of reactions (1) Handling and care of materials (3) Planning and carrying out chemical experiments (3) Usefulness and applications (4, 6) Safety norms (5) Critical evaluation of reactions in the environment (5)

C. The methodology for teaching chemical change

1. The tendencies that were observed in the role that the pupils' ideas play in the different activities are as follows:

A majority tendency to consider the pupils' conceptions as the knowledge which they have had to learn over the course of doing the activities, so that it is a matter of their applying these concepts to somewhat different situations (other exercises or laboratory activities). This tendency involves, in fact, not starting out by taking what the pupils' think into consideration. It rather assumes that the pupils have acquired new knowledge (by means of the teacher's explanations or by carrying out activities), and that it is this new knowledge that they bring into play. This tendency is especially notable on finalizing the subject, although it is also expressed in the initiation activities in the form of conceptual prerequisites that the pupils must process in order to develop the new knowledge. For example:

> GROUP 5: "The lesson will start out with open questions, which would be asked to ... find out if they have the prior concepts of atom, gram, mole, and molar volume. If not, the teacher will try to clarify by insisting on it by way of practical exercises. The topic will not be begun until the prior knowledge has been assimilated by all the pupils."
> GROUP 6: "Carry out a brief recapitulation of [what had been done] before (atom, molecule, element, Periodic Table, ionic and covalent bonds, and formulation) to start our topic, asking the pupils questions about these prior concepts."
> GROUP 4: "We will conclude the topic with two types of activities: Abundant formulation exercises which may or may not have to do with chemical reactions. They will also do written chemical reactions and it is necessary to balance them. The aim is that the formulation part (as being very important) is well learnt and assimilated."
> GROUP 3: "Explain that in the case of the decomposition of mercury oxide by heat, we would write: $2HgO \rightarrow 2Hg + O_2$
> Balance equations by trial and error or by equations: $4P + 5O_2 \rightarrow 2P_2O_5$
> Do other chemical equation exercises."

Another tendency, although in a minority, while not taking into account the pupils' ideas about the different items of the content that is to be taught, at all events aims to gather their ideas so as to awaken their interest and participation. Group 1 is the most representative of this tendency.

> GROUP 1: "Beginning of the lesson: We shall look for curious items of news that might motivate them with respect to the topic (chemical weapons, possible future of mankind, ...)."
> "As colophon, we would have a fancy dress party. Everyone would dress up as what they most liked or had been surprised about in this topic."

Also in a minority is the tendency, represented above all by Group 2, in which the pupils' conceptions form the starting point. This also sets out the need to contrast conceptions amongst the pupils themselves and then attempt to lead them towards an overall body of knowledge that is considered desirable.

> GROUP 2: "We start by asking: What changes of this kind (physical - chemical) do you know? As they name changes, these will be written up on the board. Then they are asked to arrange them by common characteristics. If they are not able to do this, they will be guided until they arrive at the physical and chemical changes."

2. The activities that are proposed for teaching chemical change are characterized by the following aspects:

- Most of the activities that the different groups propose are organized around the observation of phenomena. The essential core of most of the activities is, therefore, an empirical referent (burning paper, bicarbonate and vinegar, sulfuric acid and zinc, etc.) which is used either to infer concepts (especially in the initial and development stage activities), or for the pupils to apply their acquired knowledge (in the finalization activities).
- These activities are usually followed up by others centred on the teacher's explanation of the same or different concepts, and by exercises (especially to deal with the quantitative aspects of chemical changes).
- The activities that present the greatest diversity of settings are those which are used to initiate the process of teaching/learning chemical changes. They focus on: the pupils' interest (Group 1), the pupils' conceptions (Group 2), empirical referents (Groups 3 and 4), or conceptual prerequisites (Groups 5 and 6).
- Each group combines all these organizing elements of the activities into their own particular sequence. One can, however, appreciate certain similarities, as shown in the diagram (Figure 2).

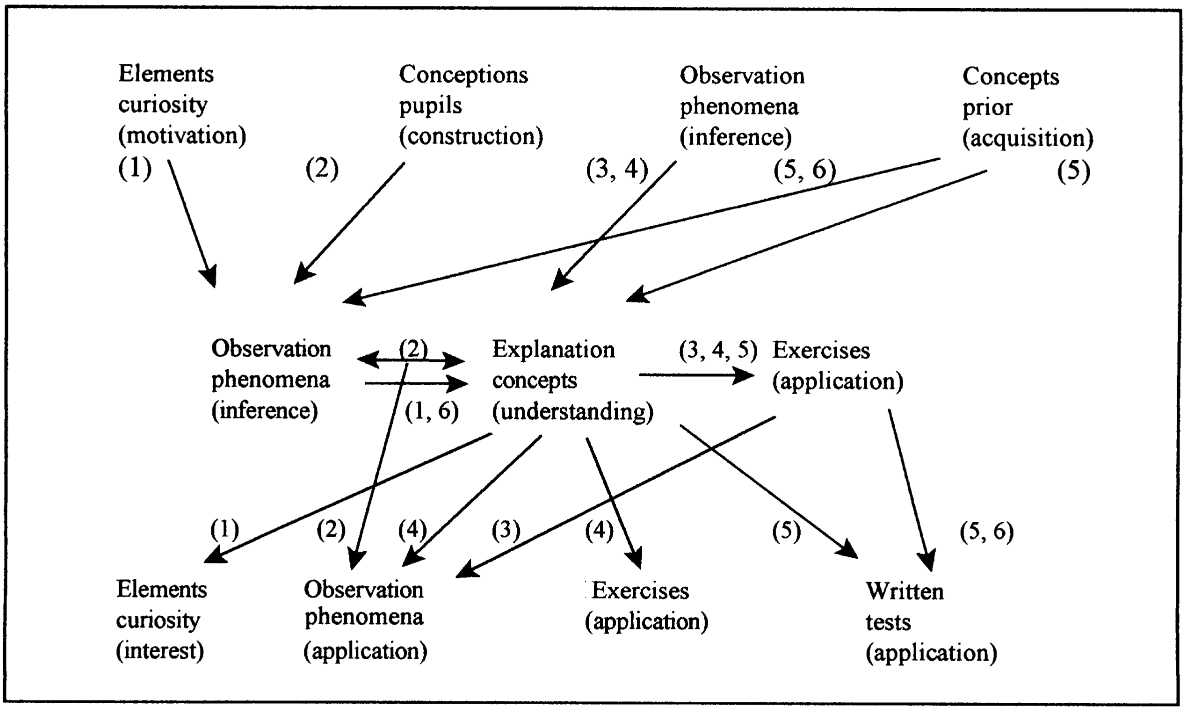

FIGURE 2. *Educational sequence proposed by each group. In parentheses is the number identifying each group.*

- In most cases, the linear sequence of content proposed by each group forms the thread connecting the activities. This does not necessarily mean that there is any particular order in the teacher's explanation, however.

3. Another of the aspects characterizing the teaching methods that the groups proposed is the role played by the teacher and the pupils in the planned activities. In the entire sequence of activities (initiation, development, and finalization), one finds that it is the teacher who sets the experiments, questions, and exercises, in sum all of the activity developed in the classroom. Consequently, the pupils are expected to do the experiments and the exercises, to answer the questions, and to listen to the teacher's explanations. We could therefore say that mostly there is a one-way relationship set up: from the teacher to the pupils.

More interactive relationships between the teacher and the pupils, while they form a minority in the overall teaching/learning process, occur as the consequence of very different activities:

In Group 1's proposal, a debate led by the teacher on the content of a film.

> GROUP 1: "Critique and discussion of the films and documentaries, led by the teacher orienting it to the topic. At the end, a summary will be handed in to the teacher of all the conclusions that they had reached."

In Group 5's proposal, a story of making a cake is aimed at giving a framework in which to debate numerous questions raised by the teacher. Also the practical activities, in which the teacher would guide the pupils' process of discovery on the basis of their observations, may give rise to another type of relationship that is not so one-way. Nevertheless, as will be seen in the following, one detects, amongst other things, an inadequate use of the concept of substance.

> GROUP 5: "We put together butter, sugar, flour, and baking powder, which are the components of a cake. What do we get? A mixture, this will seem like and taste like its ingredients. We shall add water, and bake it. What will happen? Is the new substance different from the unbaked mixture? Can it be separated out again into its original ingredients? As the example is explained, various questions will be inserted so that they deduce what a chemical change is."

Lastly, relationships of a more interactive character are described in group 2's proposal. Starting out from a teacher's question about the changes that the pupils know, the different contributions are gathered with the aim of reaching, with the teacher's help, a common scheme. This group also sets out the need for the pupils to discuss amongst themselves their own hypotheses about what is happening in different phenomena, and then to draw conclusions from their discussion.

> GROUP 2: "Activity designed to understand the usefulness of indicators. We would use natural indicators such as tea and beet juice on lemon and bicarbonate. The aim of this activity would also be to distinguish between what is acidic and what is basic, starting out always from what is known and concrete, to get later between all of them a general definition. They will work in groups to test individual hypotheses and originate conclusions."

In sum, the methodology that the groups of prospective teachers propose for teaching chemical change is characterized by:

- A majority tendency based on a mixture of two elements: the pedagogical application of an empiricist version of the scientific method (activities of observing phenomena so as to infer concepts) and the teacher's explanation for the said concepts to be understood. In this tendency, the pupils' ideas are either not taken into account or are considered to be conceptual prerequisites that the pupils must possess. Teacher-pupil interaction is a rather one-way relationship, going from the directive role of the teacher to the active role of the pupil (in the sense that the pupil carries out the activities set by the teacher).
- Combined with these majority elements there are other minority elements which make up two different methodological tendencies. One is centred on the interest and participation of the pupils, looking for everything that is capable of surprising them (Group 1). The teacher thus fulfills a role of preparing all those activities that are potentially motivating for the pupils (news items, films, theatre, fancy dress parties, ...). Everything seems to indicate that what is being sought is above all an attitude that is favourable to learning. The pupils' ideas are therefore considered to be a manifestation of their interest in the subject, but not as knowledge that has to be encouraged to evolve. Another tendency is centred on the pupils' conceptions, on discussion amongst the pupils themselves, and on the role of the teacher in orienting all these ideas towards a common body of knowledge (Group 2). We must emphasize, however, that one is dealing with elements that differentiate the methodological proposals of one group from another, and not with models in the true sense (spontaneist in one case, constructivist in the other).

D. Evaluation

As can be seen from Table 5, for most of the groups the goal of evaluation is to test the learning, especially the conceptual learning, of the pupils. Only in the case of Group 5 does evaluation have more a meaning of process, i.e., one evaluates so as to foresee and overcome the difficulties that pupils will be coming up against in their learning, as well as to improve the initial programming.

There is also a majority tendency to evaluate exclusively the pupils' learning. The primary object of evaluation is the level of conceptual understanding that has been achieved, although attitudinal and procedural learning is also included. Only in Group 5 is there the aim for the programming itself to be the object of evaluation, although no specific mechanism is put forward to this end.

There is a notable diversity of instruments and specific mechanisms with which to carry out this task: reviewing the laboratory notebooks, observation of the development of the activities, and even interviews with the pupils. In this sense, Group 2's proposal stands out as being the only one that includes a questionnaire to detect pre-existing ideas on the subject at the beginning and again at the end, thus allowing a check of whether the concepts dealt with have been assimilated. None of the proposed instruments is specified, however, i.e., neither the written text nor the observation guidelines are provided.

Lastly, it is interesting to note that, of the information sources used by the groups to draft their proposals, the most privileged position is held by textbooks of the same level. Given the characteristics of these textbooks (Martín del Pozo, 1994), one can appreciate how much this source of information has influenced what and how they intend to teach chemical change. This is especially so in the following aspects:

TABLE 5. *Hypothetical constructs concerning each of the evaluation categories.*

GROUPS	EVALUATION		
	WHY TO EVALUATE	WHAT TO EVALUATE	HOW TO EVALUATE
1	To test whether the pupils have learnt (concepts and attitudes).	The learning of concepts and attitudes.	One uses: - the laboratory notebook. - the activities carried out.
2	To test whether the pupils have learnt (concepts).	The learning of concepts.	One uses: - the same test at the beginning and end of the subject. - the activities of understanding and application of the concepts that have been dealt with.
3	To test whether the pupils have learnt (concepts)	The learning of concepts.	One uses: - observation of the development of the lessons. - the pupil's workbook. - written test. - questionnaire on an activity of synthesis of what was dealt with.
4	No information is indicated referring to evaluation.	No information is indicated referring to evaluation.	No information is indicated referring to evaluation.
5	To foresee the way to overcome learning difficulties and improve the programming.	The learning of concepts, procedures and attitudes, and also the program followed by the teacher.	One uses: - objective test. - direct observation. - pupil's workbook. - classroom activities. - interviewing the pupils. - exchange of opinions with the pupils.
6	To test whether the pupils have learnt (concepts and attitudes).	The learning of concepts and attitudes.	One uses: - written test. - laboratory activities. - questions asked during the lessons.

- The linear sequencing of the content as against the use of conceptual maps or schemes.
- The little relevance given to the pupils' ideas in the teaching/learning process.
- The lack of linkage of empirical facts to conceptual frameworks and problems.
- Textbook information as content to be suitably transmitted by the teacher for the pupils to learn.
- In sum, an accumulative and empiricist view of knowledge.

Furthermore, most of the groups use curricular materials in which only experiments on chemical change are described. These materials too usually transmit an empiricist view of knowledge, encouraging the idea that it is via observation of phenomena that the concepts involved in those phenomena may be discovered. The great amount of laboratory activities that the groups include in their proposals may be a sign of the influence of this kind of material.

Only two groups (3 and 5) use the prescriptive curriculum. Its influence may be detected above all in the didactic principles of a general nature (constructivist conception of learning) rather than in the sequence of activities. This is because the official curriculum is general in characteristic, and contains no apposite specifics.

CONCLUSIONS AND SOME IMPLICATIONS FOR INITIAL TEACHER EDUCATION

The intention with the present study was to understand the content of the initial ideas of a small sample of prospective teachers on teaching chemical change, both at the level of the general principles of teaching and learning, and of essential elements of the curriculum (content, method, and evaluation). The main conclusions and implications to take into account in initial teacher education are:

Which general principles of teaching and learning do the prospective teachers bring up in their chemical change teaching proposals?

The general principles that were detected imply a reinforcement of the aspects of teaching/learning that are most assumed by the prospective teachers: i.e., those which constitute some of the central points of what Buitink & Kemme (1986) call Subjective Educative Theory. The set of these principles seems to be somewhat far from those which are most characteristic of traditional teaching/learning models (see Table 2). On the one hand, as we noted in the Introduction, there is a didactic methodology which is coherent with the scientific empiricism that has been detected in other studies of our own and of other workers. And on the other hand, there is the relative importance (only in half the groups) of considering the pupils' prior knowledge in order to achieve meaningful learning.

Amongst other factors, this may be because the prospective teachers had received a great deal of information in this regard in their courses of Educational Psychology and, above all, of General Pedagogy. Fundamental for us, however, is that this general principle, as was seen above, does not condition the methods of teaching a specific topic. It is very difficult to spell out general principles in specific teaching proposals and, in the last instance, to put them into practice. One of the main activities in promoting the gradual evolution of prospective teachers' conceptions is the analysis of just this coherence between these principles and the teaching proposals. In our teacher education course, this type of educational activity is performed before contrasting the teaching proposals that our students have drawn up with those we consider desirable.

What aspects characterize the knowledge of chemical change that the prospective teachers intend to teach?

Half of the groups did not formulate the concept of chemical change that they intended to teach, and the other half offered a definition at a macroscopic level in the midst of a conceptual field at a microscopic level. This may be an indicator that they regard content as "something already given" by the official curriculum and (even more so) by the textbooks. They would therefore see it as unnecessary for them to worry about setting out a formulation that would be ideal for the pupils, and even less to consider the question of a possible scale of formulations of increasing complexity (Porlán, 1993; Porlán, Rivero and Martín del Pozo, 1998). The content on chemical change that the prospective teachers intended to teach reflects an encyclopaedic (wide amplitude) and fragmentary (few relationships) type of knowledge which is very close to the most traditional models of teaching (see Table 2).

Thus everything seems to indicate that the transformation of knowledge about chemical change into knowledge for teaching it is a process which should be given full attention during initial teacher education. Furthermore, the desirable professional knowledge should be able to deal conjointly with discipline-level and curriculum-level conceptions, and enable prospective teachers to know how to perform didactic analyses of different sources of information (official curriculum, textbooks, curricular materials, studies of pupils' conceptions, history of the concept, etc.) and thereby be able to draft step-wise organized proposals of school-level content formulated at different levels of complexity. This is the sense in which the initial teacher education program is currently being developed with our future Primary Education teachers (Martín del Pozo, 1998; Porlán, 1998).

Which aspects characterize the educational methodology with which the prospective teachers propose to teach chemical change?

One of the main conclusions with respect to the didactic methodology is that, in contrast with the uniformity detected relative to what to teach, the predominant tone is given by the diversity of didactic routes. We could say that the didactic methodology with which the prospective teachers propose to teach content about chemical change implies a certain adaptation of empiricism to the teaching/learning process. But this adaptation is mostly situated closer to a technological focus in the broad sense: i.e., it is founded on a closed design of activities aimed at the pupils replacing their mistakes with the teacher's pre-established knowledge (Table 2). Another two methodologies are detected, however, which contain elements closer to spontaneism (with respect to awakening the pupils' interest and curiosity) as is described by Hollon & Anderson (1987) in what they call a factual acquisition orientation, where, as Aguirre, Haggerty, & Linder (1990) point out, learning is sought for as the product of an affective response, or to constructivism (in encouraging at least a minimum of work with the pupils' ideas), in a framework close to what Hollon & Anderson (1987) call a conceptual development orientation.

What and how do the prospective teachers say they intend to evaluate in their proposals for teaching chemical change?

Everything seems to indicate that the evaluation is coherent with a traditional didactic model (final check on conceptual learning by means of written tests), but contaminated by elements more typical of a tendency that is technological (Group 2: initial and final diagnosis of the level of knowledge), spontaneist (Group 1: omission of written tests, importance of the pupils' attitudes), or even more complex (Group 5: continual process of improvement of both learning and the programming itself through the information provided by quite diverse sources) (see Table 2)

To summarize, the prospective teachers' proposals for teaching chemical change were strongly conditioned by the interaction of, inter alia, their knowledge of the material to be taught (chemical changes), their general educational knowledge, and their personal experience of what it means to teach and to learn (acquired throughout their years in school). These proposals reflected a pedagogical content knowledge that is of poor quality, characterized by:

- The use of textbooks of the same level (13-14 year olds) as their fundamental referent in selecting content. They also used books centred on “chemical experiments for childrens" as their basic referent in selecting practical activities.
- A linear sequencing of the content, following the encyclopaedic and fragmentary logic characteristic of the textbooks that they used.
- A closed sequence of laboratory observation activities which, directed by the teacher, would allow the pupils to infer the target concepts.
- A series of instruments, especially written tests, to check whether the pupils had acquired the previously established body of knowledge.

In sum, the prospective teachers' initial ideas on teaching chemical change may be characterized by a model which they mean to be an alternative to the mere verbal transmission of content by the teacher, but which nevertheless retains essential characteristics of the traditional model (above all in content and evaluation). In initial teacher education, these ideas form the starting point in the process of constructing pedagogical content knowledge which is more in harmony with a constructivist view of science teaching (Driver and Oldham, 1986), especially in its attitude to practical work (Hodson, 1994) and to the pupils' ideas (Driver, Guesne and Tiberghien, 1985; Osborne and Freyberg, 1985).

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