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RESEARCH REPORT

Teaching Models in the Use of Analogies as a Resource in the Science Classroom

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The present work discusses, firstly, different dimensions that characterize the use of analogies in the classroom. Foremost among these are the pupil's level of activity and the degree of monitoring carried out by the teacher. Secondly, the routines declared by a group of science teachers (n = 73), when they described their classroom activity in using analogies, are analysed. It was found that most of the teachers corresponded to traditional models for the use of analogies, or, in the best of cases, to models based on meaningful learning by transmission/reception of previously elaborated knowledge. Finally, some implications for teaching and teacher education are discussed.

Keywords: *Analogies; Professional development; Hypothesis of progression; Teaching models; Teaching profiles*

Introduction

This work is situated at the intersection of two burgeoning lines of research—the study of analogies as an educational resource, and the framework of teaching models. In it we attempt to establish some of the dimensions that characterize the use of analogies in normal practice. These dimensions are then used to define different models of teaching with analogies, establishing possible itineraries for the evolution of the teachers in this area.

By "teaching models" we understand different prototypical, idealized forms of conceiving the processes of teaching–learning as a function of the teachers' professional knowledge. A given teacher does not always teach in the same manner, but is

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able to adjust to different models of teaching according to the context. Nevertheless, the usual case is that every teacher shows a tendency towards a particular model depending on the stage their professional development has reached (Porlán & Rivero, 1998).

To speak of models of teaching with analogies involves defining a desirable model to serve as an ideal of reference. It likewise implies considering a more primitive model of intervention of a traditional type, and a set of intermediate transition models that permit the definition of possible itineraries for evolution. From our point of view, the work that has been carried out on analogies to date is insufficient for these purposes, which makes it advisable to begin studies in this field from new perspectives.

Most studies have either been limited to evaluating the effect of analogies on students' learning (Black & Solomon, 1987; Brown & Clement, 1989; Clement, 1993; Dupin & Joshua, 1989; Friedel, Gabel, & Samuel, 1990; Oliva, Aragón, Mateo, & Bonat, 2001a; Stavy, 1991; Vosniadou & Schommer, 1988; and others), or been centred on using this resource in textbooks (Aragon, Bonat, Cervera, Mateo, & Oliva, 1998; Curtis & Reigeluth, 1984; González, 2002; Thiele & Treagust, 1994, 1995). However, there have been very few studies that, through observation of class sessions (Dagher, 1995b; Heywood & Parker, 1997; Treagust, Duit, Joslin, & Lindauer, 1992) or reports contributed by the teachers and/or students on the subject (Jarman, 1996; Oliva, 2003; Orgill & Bodner, 2004), analyse how the teachers use analogies in their daily practice (Duit, 1991; González, 2002). This hinders any diagnostic work on the present situation of the use of analogies in the science class and is consequently an obstacle to the possibility of extracting useful implications for teacher education.

One also detects only a scant connection between the study of analogies and research on teaching models (traditional, technological-transmissive, independent discovery, socio-constructivist, etc.) (Azcárate, 1999; Garcia, 1999; Gil, 1983, 1993 Jiménez-Aleixandre, 2000; Martín del Pozo & Porlán, 2001; Porlán & Rivero, 1998), and on teacher thinking and professional development. Although several works exist oriented towards describing how analogies are usually employed or how one can improve their use, there has been an apparent lack of concern in studying the relationships between the diversity of aspects involved. The existing literature is therefore insufficient to establish a spectrum of possible models of teaching through analogies, and hence to plot educational itineraries that can help in the evolution of models of teachers' actions.

Demarcating models of teaching through analogies requires one in the first place to define different routines that characterize the behaviour of teachers faced with the use of analogies. It also implies later correlating these routines, distinguishing action scripts; that is, factors that bring together different routines that usually appear conjointly. This must be done without losing sight of which are the general models of science teaching. In this article we dedicate space to all this with the intention of providing a general framework in which to situate different ways of using analogies in science education. Finally we contribute data on the models towards which the components of a sample of secondary education science teachers tend.

Dimensions for Characterizing Teaching Action in the Use of Analogies

We constructed Table 1 on the basis of the literature on analogies in science education. It presents the different dimensions, subdimensions, and indicators used to describe the use of analogies. We do not believe that this is an appropriate place to review the conclusions obtained in the literature on each of these points. The interested reader should consult the cited references or the available literature reviews (Duit, 1991; González, 2002). Nonetheless, we do find it of interest to define the field of study, clarifying the significance of each of those dimensions and subdimensions. To this end we shall devote the following subsection.

Table 1. Dimensions and subdimensions that characterize teaching through analogies

Dimensions	Subdimensions	Indicators and categories or corresponding values
The nature of the analogy	Content dealt with by the object	Theme and topic of the object domain's curriculum
	Nature and familiarity of the analogue	Area of origin of the analogue domain (science versus non-science)
		Condition or level of abstraction of the analogue in relation to the object: concrete–concrete, abstract–abstract, and concrete–abstract
	Analogical relationship established between the object and the analogue	Type of relationship: structural, functional, or structural–functional
		Extent of similarity between the object and the analogue: intra-domain versus inter-domain
The educational context in which it is planned and developed	Manner in which it is planned	Planned versus improvised
		Thought up by the teacher versus taken from other teachers, textbooks, other students, etc.
	Location of the analogy and the analogue in the didactic sequence	Part of the lesson in which the analogy appears: at the beginning, during the development, or as a final recap
		Position of the analogue with respect to the object: the analogue is presented beforehand (as an advance organizer), during the explanation (inserted), or after (as a post-synthesizer)
	Degree of activity allowed the students	Activity versus teacher explanations
		Student initiative (personal analogies) versus prefabricated analogies

Table 1. *Continued.*

Dimensions	Subdimensions	Indicators and categories or corresponding values
		Presence of teacher–student or student–student discussion as to the meaning of the analogy versus teacher monologue
	The teacher's management of follow-up and regulation	Prior explanation of the analogue versus no explanation
		Evaluation as to how the students interpret the analogy versus no evaluation
		Demonstrating the use of the analogy by using it to make predictions and evaluating them
		Guidance of the students' understanding of the analogy versus no guidance
		The identification of analogy as strategy versus implicit use
	Degree of explicitness and development of the analogy	Presentation mode: analogy, simile, or metaphor
		Level of enrichment: simple analogies, enriched analogies (clarifying relationships, advantages, and limitations), or extended analogies (multiple analogies)
	Support resources	Drawings, or not
		Bridging analogies, or not
		Models and/or simulations, or not

The Nature of Analogy

One fundamental aspect is the intrinsic nature of analogy. Here we are referring to such questions as: Which is the "target" of the analogy? What is the degree of familiarity or abstraction of the analogue? What is the type of parallel or similarity relationship between one and the other domains of the comparison?

With respect to the first point, there have been several comparisons of the frequency of analogies in the different sciences: physics, chemistry, biology, and geology (Curtis & Reigeluth, 1984). Other studies have determined the frequency of analogies in each subject in the curriculum: electrical current, ecology, chemical change, living beings, terrestrial dynamics, and so on (Aragon et al., 1998; González, 2002; Oliva, 2003; Thiele & Treagust, 1994).

As to the nature of analogy, its degree of familiarity or proximity to the context of daily life has been studied—science, non-science (Aragon et al., 1998)—and likewise its "condition" or level of abstraction in relation to the object: concrete–concrete, abstract–abstract, and concrete–abstract (Curtis & Reigeluth, 1984; González, 2002; Jarman, 1996; Thiele, Venville, & Treagust, 1995).

Finally, it is usual to speak of the type of relationship that links the target and the analogue (Curtis & Reigeluth, 1984; González, 2002; Jarman, 1996; Thiele & Treagust, 1995; Theile, Venville, & Treagust, 1995), and also of the scope of the corresponding similarities (Brown & Clement, 1989; Oliva et al., 2001a; Vosniadou, 1989). Thus, following the tradition of studies initiated by Curtis and Reigeluth, one speaks of a structural-type relationship when the target and the analogue are similar physically or in the way they are constructed, while one speaks of functional analogy when the similarity is established in how it functions or operates rather than in the apparent structure.

We can confer different statuses on the process of analogy as a function of the level of similarity between the object and the analogue. Thus, Vosniadou (1989) and Thagard (1992) distinguish between inter-domain and intra-domain analogies. The former are analogies that only have a figurative sense (Oliva et al., 2001a; Sarantopoulos & Tsaparlis, 2004), with no intention of going further than mere comparison. The latter relate phenomena for which a single unifying theory exists, and thereby play a key role in generalization processes. Brown and Clement (1989) also make a similar distinction when they differentiate between analogies in which only abstract traits are shared between the object and the target, and analogies in which material characteristics are also shared.

The Educational Context of Planning and Development

We shall now consider the methodological aspects related to the planning and development of analogies. In particular, we refer to such factors as: how planning is carried out, the location of the analogy in the educational sequence, the degree of activity and initiative conceded to the student, the level of follow-up and regulation on the part of the teacher, the depth to which the analogy is presented and developed, and the type of support resources used.

To date, there has been little study of how teachers plan the analogies they employ. Jarman (1996) and one of our previous articles (Oliva, 2003) are two of the few studies of this type. In both, distinctions are made between planned analogies and improvised analogies, and between teachers' personal analogies, devised by themselves, and those taken from other teachers or from the texbooks.

Analysis of the location of the analogy in the educational sequence has, however, attracted much greater attention from researchers. In some cases, the said location has been understood as the placing of the analogy in the general sequence of a lesson. A distinction is made between analogies used at the beginning of the lesson by way of introduction, analogies inserted into the development of the lesson, and analogies added at the end by way of recapitulation (Aragon et al., 1998; Oliva, 2003). In other cases, however, the location of the analogy has been understood as the position of the analogue within the educational micro-sequence into which it is inserted. Thus there is a distinction between analogues that appear before the target as an advance organizer, analogues that appear as embedded activators in the explanation of the object, and analogues that are introduced *a posteriori* as post-synthesizers (Curtis & Reigeluth, 1984; González, 2002; Thiele & Treagust, 1994).

Neither has the degree of importance conceded to the student during work with analogies in the classroom attracted much attention, perhaps because the use of analogies is in many cases guided by a model in which the teacher explains, and the students are limited to learning the analogy proposed by the teacher. From this perspective, various criteria have been used to promote an active role of the students in the elaboration of the analogy: if the analogy is constructed as part of some activity that the students carry out in the classroom; if some type of initiative is conceded to the students in its construction; or if the students can participate in discussions as to the meaning of the analogy they are using.

Thus, in Oliva, Aragón, Mateo, and Bonat (2001b) an educational proposal is presented oriented to the active participation of the student in the elaboration of analogies. In Else, Ramírez, and Clement (2002), one finds various ways of involving the student cognitively and metacognitively in the construction of the analogy. Some authors such as Zook (1991), Wong (1993a, b), Cosgrove (1995), and Pitman (1999) propose personal analogies generated by the students themselves (self-generated analogies). Finally, the dialogue of discussion between teacher–student or student–student about the meaning of the analogy, as against other methods centred on the monologue of the teacher in the class, is usually considered a key element in its comprehension (Brown & Clement, 1989; Dagher, 1995a; Yerrick, Doster, Nugent, Parke, & Crawley, 2003).

It is also important to consider the role of the teacher as the regulator of the students' understanding of the analogy in question. It is not sufficient for the teacher to simply present an analogy or to invite the students to actively participate in its elaboration. It is also necessary to monitor the students throughout the process. To this end, the inclusion of preliminary explanations of the analogue is suggested, with the aim of making it easier for the students to gain a good understanding of it (Curtis & Reigeluth, 1984; González, 2002; Iding, 1997; Newton & Newton, 1995; Thiele & Treagust, 1995). It is also usually considered important for the teachers to evaluate how the students interpret the analogy (Dagher, 1995a, b; Duit, 1991; Iding, 1997; Newton & Newton, 1995) and to guide the process instead of assuming that the students always understand the analogy in the desired way (Dagher, 1995a; Mason, 1994; Newton & Newton, 1995; Oliva et al., 2001b). Finally, it is also common to evaluate the formulation and evaluation of predictions as a way for the students to test the utility of the analogy they are dealing with (Mason, 1994). Prior identification of the analogy, as a teaching–learning strategy, is also frequent, rather than simply proposing its implicit use (Gonzalez, 2002; Iding, 1997; Thiele & Treagust, 1994, 1995).

Describing the context in which an analogy is developed in the classroom implies knowing how explicit the analogy in question is. For this, one can speak of the mode in which the analogy is presented; analogy *per se*, simile, or metaphor (Dagher, 1995b; Aragon et al., 1998). We would recall in this sense that the first is the case if all the elements of the comparison are expressed explicitly. For example: “atoms are to a crystal what the joints are to a lattice”. But if not all the elements are made explicit, one has a simile or a metaphor. The difference between the latter two is rather subtle. While in the simile the relationship is only the comparison—“a crystal is like a lattice”—in the metaphor an identification is established although only in a figurative sense—“the crystal lattice” (Gilbert, 1989; Dagher, 1995b; Duit, 1991).

Another more frequent way of describing the degree to which an analogy is explicit has been through its degree of “enrichment”. This notion was also introduced in the pioneering work of Curtis and Reigeluth (1984). Later work has dealt with this same variable although with distinguishing nuances (González, 2002; Heywood & Parker, 1997; Jarman, 1996; Thiele & Treagust, 1995; Thiele et al., 1995; Treagust et al., 1992; Treagust, Harrison, & Venville, 1998). In their original definition, Curtis and Reigeluth consider that an analogy is “simple” when there is only a suggestion of the similarity between the object and the analogue, without specifying details of the correspondence of attributes between the two systems being compared. An analogy is “enriched” when it is made clear what reasons support the similarity between the two systems, and possibly when the limits of the analogy are explicitly given (i.e. the cases in which the analogy fails). Finally, an analogy is “extended” when different analogies are proposed to explain the same object and/or when various aspects of the same analogy are used to illustrate diverse features of the same object (multiple analogies).

Finally, a proper definition of the context in which an analogy is developed also requires a definition of which support resources are used. Some of the resources considered are drawings (Curtis & Reigeluth, 1984; Jarman, 1996; Thiele & Treagust, 1995), bridging analogies (Brown & Clement, 1989; Clement, 1993), and models and/or simulations (Jarman, 1996; Oliva, 2003).

As one sees, there are diverse aspects that have to be taken into account for an adequate characterization of analogies in the science class. However, as we proposed in a previous work (Oliva, Azácarate, & Navarrette, 2004), it is possible to use only two of them—the level of activity of the student and the degree of monitoring of what is learnt—as the structuring factors of the different models of intervention through analogies. We believe it is possible to subsequently incorporate the other subdimensions into the resulting models.

These two aspects are, in our opinion, those that best describe the roles of the student and of the teacher in the process of teaching–learning from a constructivist point of view (Driver & Bell, 1986; Novak 1987; Pope & Gilbert, 1983), a viewpoint that we share. Driver (1986), for example, summarizes this point of view in four premises: what is in already in the brain about what is going to be learnt is important; making sense of something involves establishing relationships; someone who is learning actively constructs meanings; and students are responsible for their own learning. In this context, we can postulate the existence of two key factors that condition how analogies are used by teachers: their interest in encouraging situations of students’ active participation in the construction of the analogies being considered; and whether or not they monitor the students’ process of significant learning and self-regulation.

Different Teaching Models in the Use of Analogies

The current literature suggests that one of the principal limitations of analogies resides in the processes on which their use is based. Most often, analogies are regarded as artefacts that the teacher invents and transmits to the pupils. Given, however, the constructivist premises of learning set out by Driver and Bell (1986), one has to accept the importance of devoting more time and effort to ensuring that the pupils make sense of the analogy that has been developed (Clement, 1993). We would thus rather be inclined towards imagining an analogy as something that is generated through a series of activities (Oliva, 2005a).

Clearly, not all analogies can be considered to be educationally useful. In this sense, we think that the construction of analogies on the part of the students should not left as a purely autonomous process, but should be accompanied by constant feedback from the teacher and the learning materials. The teacher will find it useful to evaluate whether the students understand the analogy in the sense required, or, on the contrary, are misunderstanding it or understanding it in a literal sense. It is not enough for the teacher to merely present an analogy, or just invite the students to take an active part in its construction (Oliva, 2005a).

We believe that unfortunately these two factors—activity and monitoring—do not always accompany the models of teaching with analogies that teachers follow in the classroom. Hence our interest in defining some of the teaching models that one may come across in terms of whether or not each of those factors are present (Oliva et al., 2004). This will be the focus of our attention in this work in connection with a more general taxonomy of teaching models (traditional-transmissive, meaningful transmission–reception of knowledge, independent discovery, socio-constructivist) (Figure 1).

The different possible combinations of high or low levels of student activity and of the degree of monitoring give the four models whose basic characteristics will now be discussed.

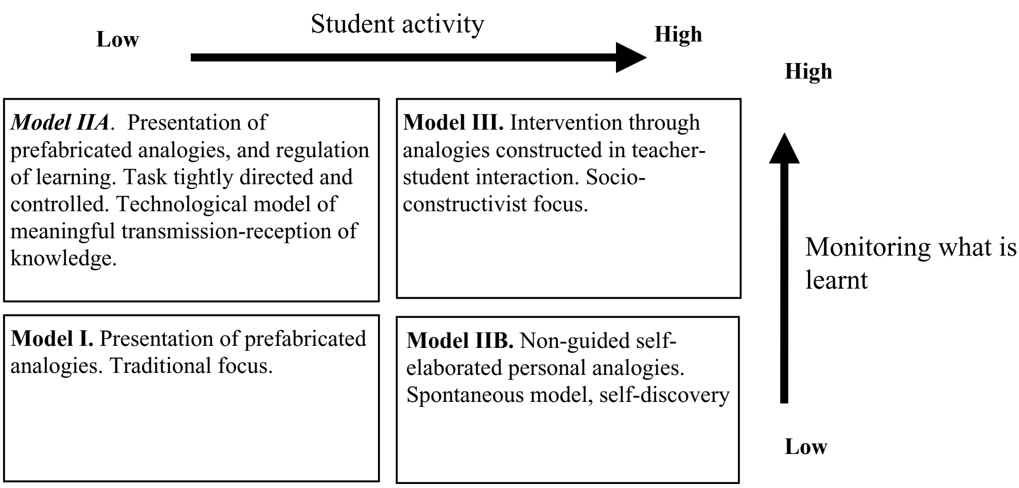

Figure 1. Different teaching models for the use of analogies in the classroom

Model I is defined by low levels of both activity and monitorizing. It involves a traditional vision of teaching that implies the mere presentation of analogies already elaborated by the teacher or of the textbook. Analogy constitutes an artefact created by the teacher or by the learning materials, and is presented to the students by means of verbal and/or visual strategies of information transmission. Learning through analogies is conceived of as an automatic process in which only one interpretation is possible for comparison, and in which it is feasible to transfer meanings faithfully from the teacher to the student. The latter is conceived of as a kind of *black box*, and any internal processes that occur while the analogy is being elaborated are ignored.

Model IIA still lies within a transmissive teaching model, but now with the addition of a constant concern to regulate the meaning that the student confers on the transmitted analogy. It is assumed that the analogy may have different meanings according to how it is interpreted and who interprets it, which leads to a certain preoccupation to orient and lead the process, avoiding transgressions and misunderstandings. Meaningful learning is valued, even though still from a standpoint that is very close to a scheme of teaching of a technological bias, based on the sequence: teach–evaluate–correct.

Model IIB does not constitute an advance with respect to Model IIA, but is rather the result of a different course in the process of evolution from the traditional model. In this case, the responsibility rests fully on the students, who invent their own analogies freely without any control, orientation, or guidance from the teacher. This is close to the models of teaching by independent discovery.

Finally, Model III, with high levels of activity and monitorizing, characterizes a model of teaching by analogies that attempts to capture the essence of the socio-constructivist approaches to science teaching–learning. The elaboration of meanings from analogy is understood as a complex interactive process, and therefore as a personal construct to be carried out by the learners themselves. This is a process of elaboration whose orientation is based on the search for answers to questions or problems in which everyone concerned participates, with a high degree of activity and autonomy in interaction in the school context: teacher, curricular materials, classmates, and so on. From our point of view, this is the most desirable model of teaching through analogies since it turns out to be the most complex as well as including the previous models. The fact that a teacher is located within this model does not mean that he or she cannot or should not act according to the other models. It is foreseeable, for example, that teachers of this type will on occasion need to have recourse to analogies that they themselves have invented (Model IIA), or propose to the students that they invent their own personal analogies (Model IIB). What characterizes these teachers then is not their actions at particular moments, but their overall model of intervention; that is, their professional teaching knowledge and capacity to coherently integrate into their teaching a certain variety of routines and working scripts in accordance with this profile.

The empirical study that we shall describe in the following was aimed at studying the importance of the two aforesaid subdimensions. From our point of view, they both constitute structural factors that may help to characterize the use of analogies according to different teaching models such as those described earlier. That these two subdimensions are picked out in no way takes importance away from the others. On the contrary, we believe that the panorama set out by the two characteristics studied in the present work is enriched by those other characteristics, since they are fundamental to establishing a hypothesis of progression between different levels or sublevels of evolution, as we shall see at the end of the work.

The Study

The study is based on the analysis of the routines declared by a group of science teachers when they described their classroom activity in using analogies. The sample comprised 73 in-service secondary education teachers: 38 in the speciality of physics and chemistry and 35 in the speciality of biology and geology. In Spain, secondary education teachers are usually science graduates who have also completed a post-graduate course specific for teaching of about one term's length. In the present case, the components of the sample were graduates in chemistry (n = 31), biology (n = 23), physics (n = 5), geology (n = 4), oceanography (n = 5), chemical engineering (n = 2), pharmacy (n = 2), and veterinary surgery (n = 1). Sixty teachers worked in state schools and the remaining 13 in private schools, in both urban and rural contexts in southern Spain. At the time of the survey, they were all taking part in in-service continuing teacher education courses. The sample had an average of 9.7 years teaching experience, with a standard deviation of 6.6 years.

The instrument used consisted of a questionnaire similar to the one we used in a prior pilot study of a descriptive type (Oliva, 2003). We then considered only the data for each of the items presented separately. But it is difficult to deduce to which model each teacher of a sample corresponds simply from the results of isolated items of a questionnaire. We think, however, that an overall study with the construction of scales based on groups of items can indeed yield results of sufficient reliability and validity for the present purposes. Hence, here we consider the correlation between the different items, and define on their basis overall teaching models such as those noted in the previous section. Table 2 presents information about the content of the items in the questionnaire. As will be seen, their object was to evaluate the incidence in the classroom of some of the indicators presented in Table 1. We considered only those that could easily be understood by teachers unfamiliar, as in our case, with some specialized terms that are used in education research on analogies. For example, no item was considered that was designed to evaluate the analogical relationship established between the object and the analogue (structural versus functional analogy). Neither was any item designed to evaluate the degree of explicitness and development of the analogy (e.g., analogy versus simile or metaphor). The reasons in both cases lay in the difficulties expressed by the teachers who participated in the pilot study in understanding and differentiating notions of that nature (Oliva, 2003; Oliva et al., 2004). Furthermore, the terminological difficulties detected in the pilot study led us to reformulate some of the other items, in order to make them more comprehensible for the new sample of teachers. We also added some items about

Table 2. Content of the different items of the questionnaire

Item number and content
The analogies I use in class …
Item 1. … I plan them beforehand when preparing the classes
Item 2. … I improvise them in the class
Item 3. … I invent them myself
Item 4. … I get them from books and/or other teachers
To introduce the analogies …
Item 5. … I present them through explanations I give to the students
Item 6. … I present them through activities which the students have to carry out
When using analogies, you usually …
Item 7. … use them as a start by way of introduction
Item 8. … use them at the end by way of recapitulation
Item 9. … use them while developing the theme
Item 10. … use them continually throughout the theme
When using analogies, you usually dedicate time to …
Item 11. … revising the source or analogue to be used in the comparison
Item 12. … checking how the students interpret the analogy
Item 13. … correcting the errors made by the students in interpreting the analogy
Item 14. … encouraging classroom discussion on the analogy in question
Item 15. … considering various different analogies to illustrate the same idea
Item 16. … using the same analogy to explain different aspects of the same phenomenon
Item 17. … analysing the similarities between the two concepts or phenomena being compared
Item 18. … using the analogies to make predictions about not very accessible phenomena
Item 19. … encouraging the students to invent their own analogies
Item 20. … analysing the limits of validity of the analogy that has been learnt
Item 21. … the students using models and simulations
Item 22. … pointing out to the students the use of analogy as a strategy

indicators that had not been considered in the pilot study, with the aim of enlarging and enriching the panel of aspects evaluated. In particular, we included one designed to evaluate the teachers' tendency to revise the analogue before introducing the analogy (Item 11), and another designed to evaluate whether or not the teachers usually explicitly identified the analogy as a strategy (Item 22).

The items were scored on a five-level Likert scale (see the example in the Appendix). In particular, the teachers had to mark, on a scale of one to five, where they perceived their teaching actions to be located. The questionnaire was preceded by a short introduction clarifying what an analogy is, together with a pair of examples. The pair of examples selected corresponded to the simile of the atom as a miniature Solar System and of the heart as a hydraulic pump. Although on this occasion the teachers were not asked to indicate specific examples of analogies that they use in their classes, there are earlier studies carried out in Spain that report the most frequent analogies in Spain's classes and textbooks (González, 2002; Medina,

Table 3. Some of the analogies most frequently used by Spain's teachers and textbooks

Domain	Target	Analogue
Physics	Direct current circuit	Hydraulic circuit
	Refraction of light	Wheels that shift direction on passing from a hard to a softer medium
	Light waves	Water waves
Chemistry	Atom	Miniature solar system
	Collisions in chemical reactions	Collisions of billiard balls
	Activation energy of a chemical reaction	Height a pole-vaulter has to clear
Biology	Heart	Hydraulic pump
	How the eye works	How a camera works
	Functioning and organization of a cell	Functioning and organization of a factory

Fernández, & González, 2004; Oliva, 2005a, b). Table 3 presents some of them corresponding to physics, chemistry, and biology.

Results

Descriptive Study of the Data

Table 4 presents the results of a descriptive item-by-item analysis, similar to that in the aforementioned previous study (Oliva, 2003). This analysis contributes data that are similar to those obtained in that previous work. The results varied between teachers, with different tendencies sometimes co-existing for the same routine. The prototypical analogy appears to be that devised by the teacher to illustrate the content of what he or she is explaining, sometimes planned beforehand and other times improvised. Throughout the process, one observes a certain degree of control or regulation on the part of the teacher. To this end, use is made of prior explanations of the analogue by way of orientation, of re-directing any mistaken interpretations that may have arisen in the students, or of making explicit the similarities that exist between the object and the analogue.

As we remarked earlier, it is not our intention here to go into any depth in the descriptive analysis. Instead, we shall concentrate on the overall analysis of the data, studying their degree of inter-relationship, determining the factors that explain most of their variance, and delimiting possible models of teacher action.

Correlation and Principal Component Analyses

Firstly, we carried out a Pearson correlation analysis. The resulting matrix had statistically significant correlation coefficients in two out of every seven cases, with high values on some occasions (e.g., $r = 0.73$, Items 11 and 12), moderate on others (e.g., $r = 0.48$, Items 12 and 20), and low or very low in the rest (e.g., $r = 0.06$, Items 2 and 18). Some items correlated negatively, in particular, those

Table 4. Descriptive study of the data

	M	*SD*
Item 1. I plan them when preparing class	3.48	0.82
Item 2. I improvise them in class	3.38	0.94
Item 3. I invent them	3.26	1.12
Item 4. I get them from books and/or other teachers	2.70	0.97
Item 5. I present them through explanation	3.84	0.76
Item 6. I set them as activities	2.44	1.08
Item 7. Advance organizer	2.58	0.96
Item 8. Recapitulation	1.96	1.01
Item 9. While developing the theme	3.56	0.82
Item 10. Continuously	3.27	0.80
Item 11. Prior review of the analogue	3.23	0.89
Item 12. Check how they are interpreted	3.00	0.97
Item 13. Correct errors	3.42	1.07
Item 14. Classroom discussion	2.26	0.93
Item 15. Various analogies for the same thing	2.86	1.03
Item 16. Same analogy to illustrate different things	2.22	0.92
Item 17. Analyse similarities	3.25	0.83
Item 18. Apply analogies for predictions	3.01	1.06
Item 19. Student-generated analogies	2.04	0.84
Item 20. Analyse limits of validity	2.96	1.14
Item 21. Students use models or simulations	2.41	0.97
Item 22. Pointing out the strategy	2.95	0.85

corresponding to opposing alternatives for the same indicator (e.g., $r = -0.55$, Items 5 and 6).

To determine the main factors or dimensions that explain these correlations, we carried out a principal component analysis. The result was a solution with eight factors, which together explained 78% of the variance. However, we did not wish to study in depth the nature of every factor, but only to identify the presence of "student activity" and "the level of monitoring" as factors of the analysis, and to calibrate their importance within the whole. We therefore opted for a more restrictive solution that preserved only the truly most important factors or components.

For this purpose, we used the scree plot of the analysis presented in Figure 2. Represented along the x-axis are the different factors or components entering the analysis up to a maximum equal to the number of variables involved. The corresponding eigenvalues are represented on the y-axis. These constitute a relative measure of the proportion of the variance explained by each factor; that is, they show the explanatory importance of each factor within the whole.

As can be seen, the plot shows a discontinuity between the second and third factors, and a point of inflexion just after the third. The second principal component analysis we carried out therefore preserved only three factors, with the expectation of

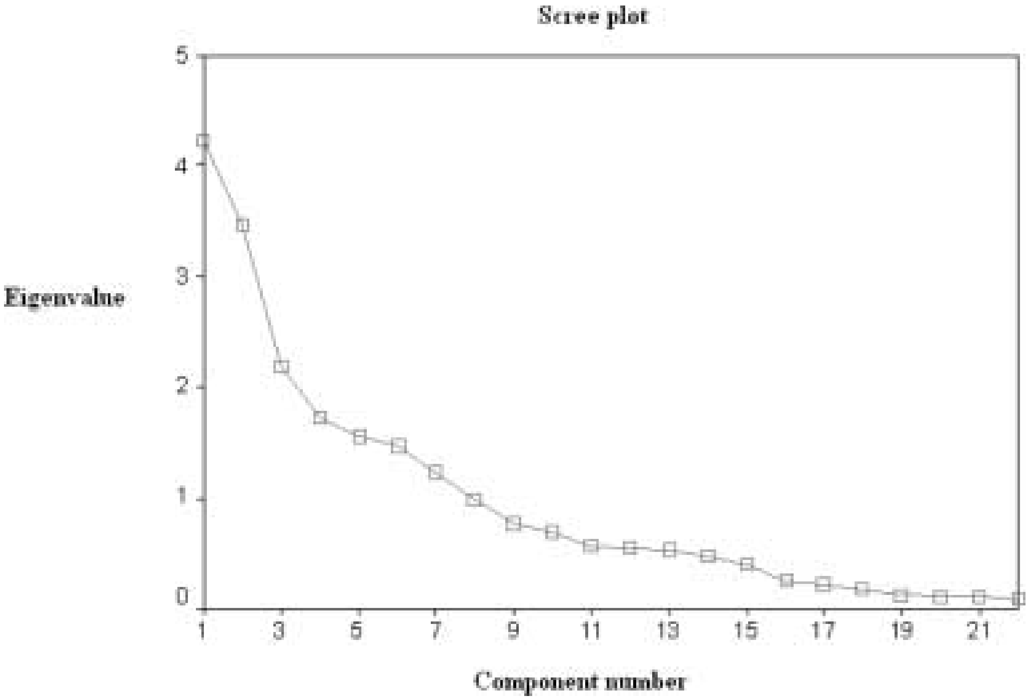

Figure 2. Scree plot for the principal component analysis

identifying the aforesaid dimensions as the first two factors, and leaving a third factor to accommodate the residual weights.

These three factors together explained 45% of the variance. Table 5 presents the weights of the different items in each of the factors. Only values greater than 0.33 are listed, being those that contribute at least 10% to the factor. To define and give meaning to each factor, only those items with weights in that factor of at least 0.5 (values with a shaded background) were used.

Component "One" presented high or relatively high factor weights for Items 1, 11, 12, 13, 17, and 18. These refer, respectively, to the level of planning, the prior orientation provided by the teacher about the analogy, the control over how the students interpret the analogy, the reorientation of any mistakes, the detailed analysis of the similarities between the object and the analogue, and the demonstration of its usefulness through successful predictions. Considered together, these aspects seem to be guided by the search for meaningful learning, in Ausubel's sense of the term. It can be identified, therefore, with the teacher's level of follow-up and monitoring of the learning process, in terms of the vertical dimension considered in Figure 1. Taking this factor as the basis, the variable "Monitoring" was defined from the average of the scores of the items indicated. This variable had a mean of 3.23, a standard deviation of 0.69, and a Cronbach alpha reliability coefficient of 0.82.

Component "Two" presented high factor weights for Items 5, 6, 14, 19, and 21. These refer to the mode of presenting the analogies (activities versus teacher

Table 5. Saturation values on each component

	Component (factor)		
	1	2	3
Item 1. I plan them when preparing class	0.623		
Item 2. I improvise them in class		–0.416	0.619
Item 3. I invent them		–0.409	0.734
Item 4. I get them from books and/or other teachers			–0.631
Item 5. I present them through explanation		–0.696	
Item 6. I set them as activities		0.714	
Item 7. Advance organizer	0.486		
Item 8. Recapitulation		0.344	
Item 9. While developing the theme			
Item 10. Continuously			0.684
Item 11. Revise prior to analogy	0.871		
Item 12. Check how they are interpreted	0.760		
Item 13. Correct errors	0.772		
Item 14. Classroom discussion		0.817	
Item 15. Various analogies for the same thing			0.582
Item 16. Same analogy to illustrate different things			–0.445
Item 17. Analyse similarities	0.625		
Item 18. Apply analogies for predictions	0.561		
Item 19. Student-generated analogies		0.552	
Item 20. Analyse limits of validity	0.454	0.353	
Item 21. Students use models or simulations		0.616	
Item 22. Pointing out the strategy	0.474		

explanations), whether or not they are discussed with the students, the students' possible contribution of self-generated personal analogies, and the students' work with models and/or simulations. From these results, one concludes that this dimension is related to the students' participation and initiative in the elaboration of the analogy, in line with the horizontal dimension in Figure 1. Following the same criterion as used before, in this case dimension "two" was used to define the variable "Activity". This variable had a mean of 2.26, a standard deviation of 0.65, and a Cronbach alpha reliability coefficient of 0.75.

Finally, Component "Three" appeared to be a residual factor in which most of the items not related to the first two were partially saturated. Although it seems closely related to the origin of the analogy and the way in which it is planned, we will not go further into the nature of this other dimension as its analysis lies outside the objectives of the present study.

The results for both the variable "Monitoring" and the variable "Activity" were re-coded into two groups or levels according to whether their respective values were below or above the mid-point of the scale (low level, $1 \leq x < 3$; high level, $3 \leq x \leq 5$). Following this criterion, 29 (39.7%) of the teachers were grouped in the "low" level

Table 6. Distribution of teachers in different models of using analogies in the classroom

Model	Monitoring	Activity	Frequency	%
I	Low	Low	29	39.7
IIA	High	Low	36	49.3
IIB	Low	High	–	–
III	High	High	8	11.0
Total			73	100.0

of "Monitoring", and 44 (60.3%) in the "high" level; 65 (89.0%) of the teachers were grouped in the "low" level of "Activity", and 8 (11.0%) in the "high" level. These results indicate medium–high levels for the variable "Monitoring" and very low levels for the variable "Activity", confirming the results of a previous study (Oliva, 2003).

The combination of high and low values of these two variables permits us to identify four groups or levels in line with those shown in Figure 1. The frequency distribution of the teachers in each is presented in Table 6. Table 7 presents the descriptive results for the "Monitoring" and "Activity" variables corresponding to these subsamples.

As can be seen, most of the teachers were grouped into the two first profiles: traditional-transmissive (Model I) (n = 29), and models based on meaningful learning by reception of previously elaborated knowledge (Model IIA) (n = 36). None of the teachers, however, corresponded to a model that conceives of learning by analogy as an autonomous personal phenomenon (Model IIB). A small fraction of more evolved teachers corresponded to a model of a socio-constructivist type for the use of analogies (Model III) (n = 8). It is, however, necessary to indicate in this last case that only a moderate level of activity was allowed, as is shown by the discrete value of the average obtained for that variable (Table 6). Hence, this fraction of the teachers might be regarded as at an incipient level of this model, and therefore susceptible to progress in this dimension.

Conclusions and Implications for Teacher Education

Starting from some previous work (Oliva, 2003; Oliva et al., 2004), in this article we have proposed a theoretical framework of models of teacher action for the use of

Table 7. Descriptive study of the results for the Regulation and Activity variables

	Model I (n = 29)		Model IIA (n = 36)		Model III (n = 8)	
Dimension	*M*	*SD*	*M*	*SD*	*M*	*SD*
Monitoring	2.54	0.37	3.68	0.43	3.72	0.30
Activity	2.17	0.50	2.11	0.63	3.30	0.15

analogies as a resource in the science class. Taking this framework as a reference, we chose the students' activity and the teacher's monitoring level as structural dimensions with which to demarcate general criteria for intervention through analogies. We also contributed empirical data in favour of this framework in identifying these two dimensions as the two principal components in a factor analysis. Finally, the data were used to group the participating sample into the four models that were defined. It was found that most of the teachers corresponded to traditional models for the use of analogies, or, in the best of cases, to models based on the meaningful transmission–reception of knowledge. A small fraction of teachers were found to be close to a socio-constructivist model in the use of analogies, while no teachers fitted the model in which analogy is conceived of as a process of autonomous construction by the students. Together, the data indicate a use of analogies that is fairly distant from a desirable model of intervention (Model III).

An overall analysis of models of intervention through analogies, such as that proposed here, could be of use in the search for more suitable teaching education strategies. These strategies would be aimed at fostering the evolution from the scripts and routines that characterize teachers' current use of analogies towards others that are more in accordance with the use that we consider desirable. One would thereby be contributing to the professional development of the teachers involved. Figure 3 presents a possible teacher education itinerary oriented to encouraging the evolution of teachers' scripts and routines in the use of analogies, following a hypothesis of progression.

As one observes, although there were no teachers even approximately close to Model IIB, this model was not eliminated from our evolutionary itinerary. For one thing, we think that it could be present at particular moments in some teachers even without being their preferred model. Indeed, we believe that there exist neither pure models in educational practice nor clearly defined stages in a teacher's real development (Porlán & Rivero, 1998). And for another, we believe that the jump from Model IIA to Model III perhaps requires trying out routines of Model IIB, which are without doubt simpler and easier to put into practice than those of Model III. Hence, the proposed itinerary should not be interpreted as a linear and one-way process through which all teachers should pass, but rather it should be understood flexibly, admitting fluctuations, cycles, and even the alternation of models (Porlán & Rivero, 1998).

Also, in the proposed itinerary, we did believe it opportune to include three new intermediate models: Model IIA "advanced", Model IIB "advanced", and Model III "advanced". The purpose is to allow for a certain degree of improvement and consolidation for each of the preceding models.

The proposed scheme also constitutes a theoretical framework of interest in orienting future research on how teachers use analogies in their classes with a view to applications in teacher education. In particular, in a work we are currently preparing, we analyse the possible differences between the models of teacher action using analogies in terms of such factors as the length of time the teacher has been teaching or the speciality (physics and chemistry, biology and geology).

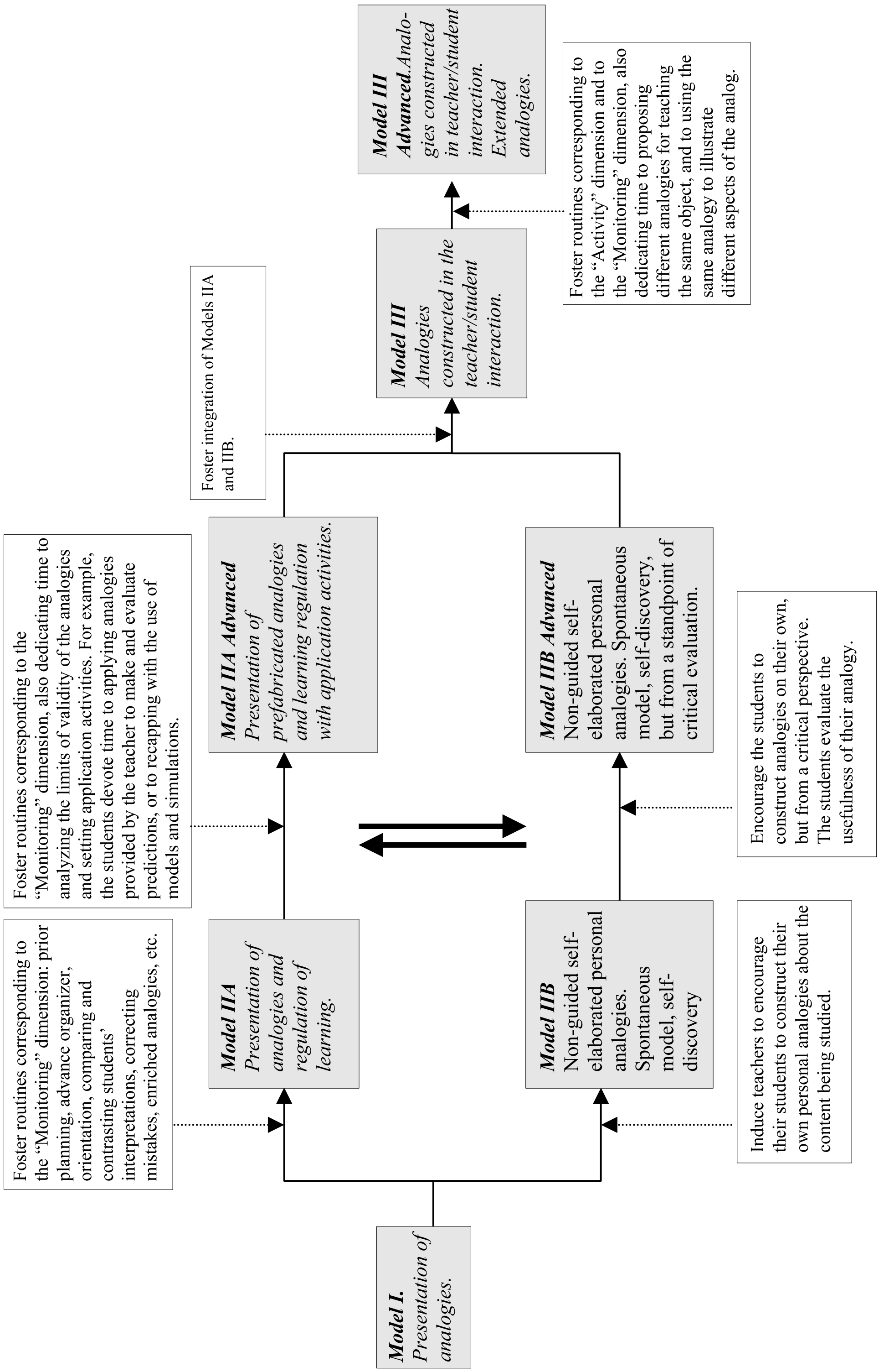

Figure 3. Proposed progression itinerary of scripts and routines for teachers using analogy as a resource

Before ending, it is convenient to provide some remarks about the focus adopted in the present work and its possible limitations. Firstly, we would note that the data show that the analogies the teachers use in the classroom come from their own opinions and insights, and not from direct classroom observation as would be the ideal case. Future studies should therefore be carried out using other ways of gathering information and/or applying techniques of triangulation. Secondly, one should note that the fact of using a written questionnaire in order to survey a large sample forced us to select only determined routines, and not all those considered in the literature (see Table 1). We chose only those facets that were easy to express in writing and intelligible to teachers unfamiliar with education research in general, and research on analogies in particular. For this reason, new studies should be carried out that also consider these other dimensions in order to enrich the panorama that is offered.

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Appendix. Examples of questionnaire items

Circle the corresponding option:
1 Totally disagree
2 Mostly disagree
3 Undecided
4 Mostly agree
5 Totally agree
The analogies I use in class…

Item 1. I plan them beforehand when preparing the class	1	2	3	4	5
Item 2. I improvise them during the class	1	2	3	4	5
Item 3. I invent them myself	1	2	3	4	5
Item 4. I get them from books and/or other teachers	1	2	3	4	5