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A Proposal for Textbooks Analysis: Rhetorical Structures

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ABSTRACT: The present study relates to a research line in didactics of science that focuses on the function that sign systems or semiotic modes have in communicative interactions in science classrooms. The study was conducted by 20 secondary and university science teachers who belong to the same research group LIEC (*Language and Science Teaching*) at the Universitat Autònoma de Barcelona (UAB). This group is devoted to the study of the relations between language and science teaching, and is centred on the analysis of textbooks, because these are still the most used 'didactical mediators' in science teaching. The study attempted to construct indicators in order to investigate whether textbooks are adequate for didactical intervention. Such an investigation would provide useful information for better strategies both to read in class and to write more innovative textbooks from a 'didactical' point of view, i.e., textbooks that are more appropriate to support students' autonomous work in science classrooms.

Keywords: Chemistry, rethorics, textbooks

The Textbook as a Cultural Object

Educational practice requires communication processes that are conducted through different media, each with its specific languages (Márquez, Izquierdo, & Espinet, 2006). Such languages consist of structures that reveal their intentionality, which can be labelled as 'rhetorical.' In the present study, the selected medium was the textbook, because this is still the mostly used didactical resource in classrooms. Martins (2001) considered that textbooks are cultural objects and semiotic hybrids (Lemke, 1988), that is, they use written verbal language and pictorial elements in the same space of the pages. From this perspective, textbooks participate in the symbolic interactions of culture, particularly of school and scientific cultures (Clément, Bernard, Quesada, Rogers, & Buggier, 2005).

In textbooks, several discursive structures can be identified. Discursive structures *materialize* the discourse on science that is taught at school and that allow specific interactions between textbook authors and readers. This conceptualization of textbooks allows establishing relations between language and science teaching, and shows the orientation that authors (and school teachers who use the books) desire for science education, and, from this perspective, textbooks constitute a remarkable research object in science education.

Bakhtin (1953) suggested that language is a human production; and its 'sub-

stance' is the social phenomenon of verbal interaction that is performed through enunciation, while the study of language should be centred on the production of enunciations. Thus, textbooks as cultural objects are the expression of their authors' enunciations, which are produced in a social context and in a specific historical moment in order to make possible classroom practices where teachers and students take part, and which will lead to new enunciations through new languages.

Textbooks must show what the 'physical and biological worlds' are and how they work. Thus, authors use resources (verbal text and imagenic or 'visual' text) that have been little studied until now from the point of view of *rhetoric* (Izquierdo, 2000; Martins, 2000). Textbooks must explain to their readers a 'world' that has already been interpreted, since it has been constructed by the authors with literary resources, in order to justify the facts of the world that readers must know. That is to say, science textbooks help readers think in a scientific way on the phenomena of the world, and such a way is adjusted to the transformations that can be performed on it (Martin & Halliday, 1993).

Ogborn, Kress, Martins, and Mcgillicuddy (1996) have shown that science teachers' explanations in class are structured as 'stories on the phenomena of the world,' stories in which scientific entities intervene and, in this way, become real and credible. Given that textbooks are still the main resource used in class, it can be assumed that it is also possible to identify in textbooks the same rhetorical strategy. For this, we should investigate how experimental facts (or phenomena of the world) are transformed into written text in the books, and to characterize the specific function of facts in the text. In order to achieve this, we will try to identify the 'experimental stories' that are narrated in textbooks and the elements that make 'stories' in the various textbooks (manuals) different to one another, but, at the same time, all capable of convincing readers that the scientific entities and theories that they should learn are believable (Gill et al., 1997, cited by Martins, 2000).

Martins (1997) stated that modern textbooks include many images and that the relations between images and text has changed. In modern textbooks, pictures are part of the text, and it is necessary to read text and images at the same time. In our research, we considered 'images' everything that has not been expressed in the written verbal code, i.e., graphs, diagrams, and photos of experiences, scientists, natural phenomena, and natural or urban landscapes. We study images on paper, always associated to a referent, even when they are abstract; images must be part of a culture, since their referent is a symbolic cultural production, set in a place and a time. This is what belongs to an everyday culture in which many social actors participate. As it happens with a written text, when we read an image, we do not only read the signs; the visual component is important and should be considered as a 'semiotic mode' that cooperates with the linguistic component (Kress, & van Leeuwen, 1997).

A new unit of analysis then emerges; we label it 'text + image.' In our research, we considered as 'units of analysis' the complex formed by written verbal text and imagenic (visual) text; this rhetorical complex constitutes a structure showing a particular instructional intentionality, since it achieves expressing teaching aims and a particular model of scientific knowledge.

The 'magisterial' lesson, which gives answers to questions that are not explicitly posed, has been, until now, very frequent in our schools. But nowadays, new class styles are being introduced; the dialogue between teachers and students is considered very important. In spite of everything, textbooks are still the main didactical tool in 'discursive' classrooms. In fact, the aim of science teaching is to convince students of the 'scientific' functioning of the world and this is difficult to do without books. But, we can suppose that textbooks of the future will adapt to the new discursive functions that are being introduced. This is why the analysis of textbooks from different points of view is necessary in order to characterize the elements that make them more appropriate to the new teaching styles (Jiménez & Perales, 2002). Thus, the aim of this study was to identify science stories in textbooks, based on the communicability and the factuability of the text.

The Investigation

We analyzed 20 lower- and upper-secondary textbooks published in the last ten years in Spain and South America. Each book was analyzed by two researchers. We performed three analyses: one on text structures, one on factual content, and a third analysis unifying the first two under a 'narrative' perspective. We have been able to characterize the story narrated by the book with the indicators that the analyses provided and we have thus identified different 'science stories' in textbooks. We have organized the data in a systemic network, which provided us the categories that give meaning to the regularities observed, as indicated in Figure 1.

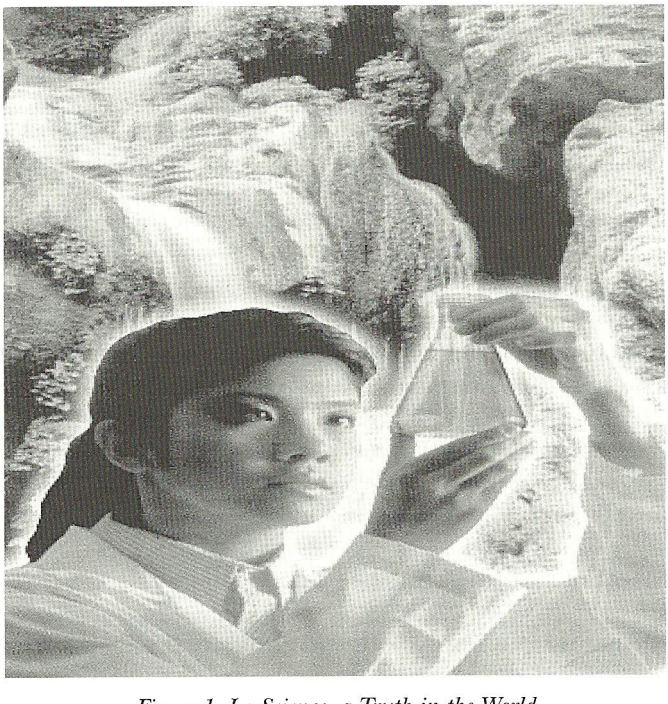

Figure 1. La Science, a Truth in the World

Analysis of Text Structures

We selected the aspects of analysis that helped us to identify differences between the texts and we left aside everything that was common between books, such as, division in chapters that are 'lessons'; correspondence between topics and a normative curriculum; presence of exercises relating to evaluations; a style that helps memorization. We identified that textbooks present the following differences: (a) Opinions on science that allow to identify 'science models': dogmatic (affirmative or 'magisterial', i.e., didactic), or problematic (with rhetorical or real doubt). (b) References to the activity that is expected from readers; such references allow identifying 'reader models': distant (disciple) or near (colleague, collaborator, and active apprentice). and (c) Indications on the development of the class, which allow to identify 'science class models': coherent (discovery, transmission, constructivism) or incoherent (there are differences between activities or chapters). In this way, we identify the *communicability* of the text (following Potter, 1996).

Analysis of the Factual Contents of the Books

Our analysis of the factual content of the books was based on two aspects:

a. References to the phenomena that are presented in the books (real, laboratory, or symbolic phenomena), that is, the concrete 'world' that is shown.
b. The way in which facts are constructed in the text: what we call 'speech acts' (definitions, comparisons, deductions...) (Austin, 1982; Potter, 1996).

The first aspect shows that we can select the examples (experiences, phenomena...) in different ways and, the second, that references to the world (examples) are 'literary' and have been constructed in the text through linguistic strategies that, in the end, give them different meanings. Indeed, it is very different to present salt dissolving in water by describing how we see it, or by arguing on the factors that influence the process, or even by defining invisible entities with which we can imagine the structure of all salts. In this way, we identify the *factuality* of texts (following Potter, 1996).

Science Stories in Textbooks

With these two analyses, which inform us on the communicability and factuality of the book, we can identify the global rhetorical structure of the text. In order to do this, it is useful to consider the whole book as a 'narration,' which allows us to establish links between communicability and factuality of the text. That is to say, we can consider that the book is a 'narration of the world,' in which facts of the world are communicated with an intention, characterized by the models of science, teacher, and student. The question behind this third analysis is: Which is the science story narrated in the book? In order to answer this question, we had to identify:

(1) The narrator and the audience that is supposed: Who narrates and to whom?
(2) The elements of authority: Who guaranties that what is said is important?
(3) The factual and conceptual elements that take part: What happens?
(4) The resources that are used in order to present facts in a scientific way:

How is scientific knowledge constructed in this story?

In order to relate the three analyses, we organized the results in a systemic network/table (Table 1) using four main categories and 18 sub-categories. The four points that have enabled us to consider the book as a 'narration' were adjusted to the categories of Table 1.

Table 1
Systemic Network of Indicators

Communicability of the text	I. Science model	Dogmatic	Affirmative 1	Narrator Audience (1)
			Professorial 2	
		Problematic	Rhetorical doubt 3	
			Real doubt 4	
	II. Reader model	Distant	Disciple 5	
		Near	Colleague 6 Collaborator 7 Active apprentice 8	
	III. Didactical model	Coherent	Discovery 9 Transmission 10 Constructivism 11	Elements of authority (2)
		Incoherent	12	
Factuality	IV. Facts of which we talk	Phenomena	Real 13	Factual elements (3)
			Laboratory 14	
			Symbolic 15	
		'Speech acts'	Definition 16	Resources (4)
			Description 17	
			Comparison-Deduction 18	

Categories I and II show the 'science model' and the 'reader model.' All the books analyzed were textbooks and consequently, in all of them, the narrator (1) is science (or teachers, or sometimes students) and student-readers were the audience. The mediators between science and readers were teachers. Consequently, the elements of authority (2) correspond to category III, that is, the model of classroom or 'didactical style.' Finally, category IV of Table 1, 'facts of which we talk,' tells us whether these are real or have been idealized (3), and what are the resources that have been used to present those facts as 'scientific' and being part of the global narrative (4).

These four categories and 18 sub-categories are proposed as indicators of the 'science story' that books tell. With these indicators, we have been able to identify these 'narrations on the material world' in all the analyzed books. The different combinations of indicators provided different typologies of stories. Actors are always the same, science, teachers and also students, but their roles are different.

The analysis of images was considered in the process of construction of the systemic networks and contributed to the meaning of the indicators (Clément & Calvalho, 2005). For instance, when one of the books talks about 'carbon chemistry,' it presents a young woman with an Erlenmeyer full of a green liquid, and, in the background, some trees and rocks. Those elements characterize a magisterial rhetoric, since they associate the study of chemistry with understanding of the functioning of nature and with the possibility of young women studying chemistry (an educational and not only scientific value), as indicated in Figure 1.

Our aim was not the classification of texts according to the stories they narrate. We wanted to show that each book presents scientific topics in a different way, according to the values to which it gives priority. This allowed us to give titles to the narratives, for instance: 'Science is surprising,' 'The world is reasonable,' 'Science: a truth that has been developed throughout history and should be taught because it is useful,' 'Everyone can understand the functioning of the world if they know chemistry,' etc. These titles aim at distinguishing the authors' intentions and at characterising textbooks as 'narrations' having the specific rhetorical function that they suggest.

Examples of Application of the Indicators

We developed several examples of application of the table (Figure 1) in order to identify different 'narrations on the material world.' We show here one of those examples, around the book to which we have given the title: Science: A truth that has been developed throughout history and should be taught, because it is useful. This story is narrated in a Spanish upper-secondary (i.e., high-school) textbook (*Química*, Quílez et al., Barcelona, 2000), which follows the official chemistry curriculum. The book is organized in chapters or lessons arranged in three modules, each developing a key idea: What is Chemistry, Structure of Matter, Stoichiometric and Energetic Aspects of Chemical Change.

In the presentation, the authors address student-readers: *In the courses of compulsory education, you have already studied some concepts of chemistry, and surely you can provide many examples of the links between chemistry and everyday life....* The story is narrated to students by a teacher who considers chemistry to be a social and cultural product, adequate to educate. *Authors have tried and presented the relations between chemistry, technology, and society from a broad and diversified dimension.* Concern for human formation of the student-readers is also shown in the attention to gender issues, allowing women to talk as teachers or scientists (see Figure 1).

Narrators offer students a knowledge to which they attribute humanistic value. *This dimension has cultural character, which, in addition, can enhance your interest... We hope that you enjoy it... This historical-cultural perspective is associated to the need to solve problems... We have insisted on the experimental aspects of chemistry. Macroscopic knowledge*

is always associated to a quantitative study and finds its justification in a microscopic point of view.

From the point of view of communicability, the book is constituted by structures of rhetorical doubt, and the elaborated narratives contribute to constructing a science model based on problem solving. The structure of the book is appropriate for the chosen teaching style, since in each chapter open questions appear, such as: *Is it possible to boil water by cooling it?* But such questions are combined with some other that only introduce theoretical answers, such as: *Is mass conserved in chemical transformations? Why is the particulate model of matter so important? What is conserved during chemical reactions?*

Text readers are, undoubtedly, students who are capable of thinking and who contribute to the story that is explained with their questions, which provoke the explanations that are constructed. For instance, some chapters begin with dialogs between a teacher (a woman) and some students. Nevertheless, the class model presented is magisterial (didactic).

> *Teacher: There exist as many kinds of elements as possible atoms.*
>
> *Pau: I understand that Lavoisier defined 'chemical element' as a substance that cannot be decomposed...*
>
> *Teacher: We should not confuse the concept of chemical element with that of simple substance...*

From the point of view of factuality, facts of the world presented are laboratory phenomena, which are linked to chemical entities rigorously, as shown in the preceding dialog, in which the teacher draws students' attention to the confusion, very frequent in chemistry textbooks, between element and simple substance. Due to this, most phenomena are reconstructed according to atomic theory or to quantitative laws. For this to be possible, the text establishes a close relationship with images (tables, graphs, pictures of atoms and particles, instruments, photos of substances...). In spite of this, the relationship seems excessively ambitious: *Based on the table describing the behaviour of channel rays, deduce which are their properties* (there is a picture showing how channel rays are formed in a discharge tube) (p. 87). In other cases, the relationship might prove unnecessary or confusing, as in the *Explanatory diagram of the foundations of filtering. Particles that are bigger than the paper pores (big blue balls) are retained (other balls, the red smaller ones, pass through the paper)* (p. 42).

In spite of the fact that the modules are introduced by a motivating image (for instance: *fireworks*, in page 85), the rest of images are more academic. As a whole, STS (Science, Technology, Society) topics are presented as readings, but they do not lead to open activities in which students can intervene: *Greenhouse effect: Radiation coming from the sun onto the earth must go through the atmosphere... What is the problem?... The world summit celebrated in Kyoto in December 1997 tried to stop gas emissions; its resolutions were deemed insufficient by many scientists.*

For all this, the model of science is transformed along the textbook. Although it is initially a model of rhetorical doubt, it finally becomes dogmatic, professorial, and excessively affirmative. The indicators with which we characterize this narration are shown in Table 2.

Table 2
The Characterization of the Science Story in the Textbook

Communicability	I. Science model	Dogmatic	Magisterial 2
	II. Reader model	Distant	Disciple 5
	III. Didactical model	Incoherent	12
Factual content	IV. Facts of which we talk	Phenomena	Laboratory 14
		'Speech acts'	Definitions Deductions 18

We also realized that the graphical project guarantees the visual unity of this book, and that it is coherent with the teaching line of 'helping students to learn the true constructed along the history by reasoning.' For example, icons are used to identify the typology of learning activity proposed to students. Other aspects of this line that is followed are the graphical presentation of chemistry as an experimental science and the association of macroscopic images of matter with the quantitative study, justified from the microscopic point of view.

From the point of view of communicability, the graphical project of the book presents a model of affirmative science by means of rhetorical structures that are *dogmatic* and, above all, magisterial. From the point of view of the 'factuality' of images, photos and drawings reproduce real facts in the laboratory. Macroscopic facts, represented by images, are accompanied by microscopic explanations expressed in symbolic language. This articulation between images becomes a rhetorical resource.

Conclusions

In our investigation, we identified 'narratives on the material world' elaborated from the articulation between verbal and imagenic (visual) text. Such narratives are rhetorical, since they guide reading leading to students' learning according to authors' finalities. Thus, we identified a rhetorical structure in textbooks, as Ogborn et al. (1996) had done when studying teachers' discourse in the classroom. Of course, science textbooks are also 'lecture-like,' but it is interesting to discover that they also have this narrative dimension, which allows readers a living approach to the 'facts of nature' that scientists study. We characterized these different 'science stories' according to their main characters, audiences, and facts that are explained. Those stories combine in different ways 'communicability' and 'factuality,' according to the educational aims of their authors. Such aims can also be identified in our study.

Analysis of the images also provided interesting results. Above all, confirmation of the contribution of images to the teaching message from the book authors. For instance, if the book presents science as 'a theoretical point of view on everyday life,' images are photos or drawings presenting everyday situations or scientific entities, but they have some traits composing 'characters' and repeated throughout the book (for instance, vectors drawn on people moving). In this way, images lead to a symbolic reading allowing to mistake everyday life for science. This is due to a special presentation of the referent, giving it a scientific value and accordingly

treating it in a special way from the graphical point of view, different from images of theoretical entities. In other books, where science is the most important thing, images presenting both abstract scientific entities and everyday facts are designed in the same way. Everyday facts 'are' science (if we can look at them in the right way), but there are no images of abstract entities constructed with everyday situations.

The visual project of textbooks presents facts of the world, or of the laboratory with photos or pictures with a degree of iconicity that guarantees the possibility of being read, since their referents become clear. And, if the pages present referents that are not clear, the books uses specific resources to help, such as representation of the same images of abstract scientific entities (atoms, vectors) on pictures or photos of everyday situations. New graphs are introduced, while their referents are constructed as a specific production of the educational culture.

From the point of view of communicability, we saw that almost all the books have rhetorical structures that '*are stories on a dogmatic science*' (either affirmative or magisterial), but they give different meaning to knowledge production. For instance, production can go from everyday life to science, or the other way round, or there can be circularity within science. We believe that these narratives are not arbitrary. On the contrary, they correspond to real discourse practices that are part of our educational system and constitute a network of meanings on science teaching and learning (that is, on their aims, methodologies, and instructional materials).

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