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Science Education in Primary and Secondary Level

An Analysis of the Discursive Transitions across Different Modalities of the Pedagogic Discourse

Vasilis Koulaidis and Costas Dimopoulos

Abstract

The aim of this paper is the mapping of the discursive transitions in school science from the primary to the secondary level as reflected in the corresponding textbooks. Our basic hypothesis is that the pedagogic discourse is constructed by the interplay of three basic dimensions, namely classification, formality and framing which correspond to the content specialization, the codes' elaboration and the agency of control of the pedagogical process respectively. According to our model each dimension can only take two values; either high (strong) or low (weak). Specifically, strong classification corresponds to subject matter epistemologically distinct from other than the scientific forms of knowledge, while weak classification means that the subject-matter is a mixture of elements derived from various knowledge domains. Furthermore, high formality corresponds to specialized codes that define reality in terms of abstractions and scientific conventions while low formality corresponds to codes resembling the vernacular ways of expression. Finally, strong classification means that the addresser of scientific knowledge (e.g. science teacher or textbook's voice) has full control over the determination of the conditions of the pedagogical process while weak classification means that at least some important aspects of this process are open to negotiation between the latter and the students.

The combination of values of classification, formality and framing produces eight different pedagogic modalities, which are labeled as follows:

- 1. Esoteric authoritarian (strong classification, high formality, strong framing)*
- 2. Esoteric liberal (strong classification, high formality, weak framing)*
- 3. Metaphorical authoritarian (strong classification, low formality, strong framing)*
- 4. Metaphorical liberal (strong classification, low formality, weak framing)*
- 5. Mythical authoritarian (weak classification, high formality, strong framing)*
- 6. Mythical liberal (weak classification, high formality, weak framing)*
- 7. Public authoritarian (weak classification, low formality, strong framing)*
- 8. Public liberal (weak classification, low formality, weak framing)*

These modalities will be used so as to map the discursive transition in school science from the primary to the secondary level as this transition is at least realized by the variation in the characteristics of the corresponding science textbooks. Specifically, the discursive characteristics related to the pedagogical notions of classification, formality and framing and projected by the linguistic and

the visual mode respectively are analysed in all the science textbooks used at the primary and secondary level of the Greek educational system. Finally, the emerging path is discussed in the light of its pedagogic implications.

Introduction

The aim of this paper is the mapping of the discursive transitions in school science from the primary to the secondary level as reflected in the corresponding textbooks. In this study school science textbooks are considered as means of regulating the pedagogic discourse of each of the educational levels they are used to and therefore as a mirror of the pedagogic transitions in science education that occur when moving from the primary to the lower secondary level. This kind of approach stems from the view that science education (and education in general) is a socialization process into the practices and conventions (i.e. the discourses) of sub-communities, in our case of the scientific community (Lemke, 1990). Within the framework of this view, science textbooks have a central role to play in this socialising process as a resource for shared meaning making (Halliday, 1978; Lemke, 1990; Bazerman, 1998).

The Issue of Textbooks in the Science Education Literature

The issue of school science textbooks has been a major research topic within the science education research tradition. During the seventies textbooks' readability studies were quite popular but interest in them gradually faded, mainly due to concerns about their validity, particularly for use in specialized texts. The interest though for science textbooks as a research topic has been sustained since a literature search in the ERIC database for studies on the school science textbooks in the period 1985-2002 revealed 222 relevant studies. These studies can be grouped, according to their particular focus, into the following categories: (a) studies which focus on elements of textbooks, such as the content, vocabulary, illustrations used, and the teaching methods promoted which are treated as simplified "castings" of the scientific structure; and (b) those considering the principles that organize the content and the form of presentation by conceiving textbooks as texts playing a crucial role in the determination of practices and social positions within the pedagogic discourse (Koulaidis and Tsatsaroni, 1996). As pointed out by Koulaidis and Tsatsaroni, (1996) *'in attempting to consider the sorts of principles that may be used in the studies categorised under (b), two crucial issues are discussed. The first issue refers to the relationship between scientific knowledge and school knowledge.... The second issue explicitly addresses the nature of the pedagogic relationship and the place of the pedagogic text within it'* (p.1)

This study belongs in the second of the two aforementioned categories of studies, since it aims at addressing both the issue of the relationship between scientific knowledge and school knowledge and the issue of the nature of the pedagogic relationship as well.

Theoretical Framework

In order then to examine the issue of how textbooks formulate the pedagogic discourse and thus capturing the corresponding discursive transitions from the primary to the lower secondary level, our basic hypothesis is that the pedagogic discourse is constructed by the interplay of three basic dimensions, namely *classification* (Bernstein, 1996), *formality* (Halliday and Martin, 1996) and *framing* (Bernstein, 1996).

In particular, 'classification' determines the epistemological relationship between knowledge systems (Bernstein, 1996). In our case, the knowledge systems examined are specialised 'scientific knowledge' and every other form of knowledge lying closer to the 'everyday common-sense' realm like mythology, religion, popular culture, practical knowledge, etc. The specialized scientific knowledge and the every-day knowledge are interchangeably employed in school science, either by presenting every-day forms of knowledge as a point of departure for the discovery of scientific knowledge or, inversely, by presenting scientific knowledge as a means for meaning making of the every-day world situations. By definition, strong classification formulates well-defined borderlines, while weak classification results in blurred borderlines between these two types of knowledge (Bernstein, 1996).

'Formality' corresponds to the degree of abstraction, elaboration and specialisation of the expressive codes (i.e. linguistic and visual) employed. Low formality corresponds to codes resembling very much the vernacular or realistic ways of expression that ordinary people use. On the other hand, high formality corresponds to the specialised expressive codes following the conventions that scientific experts use when communicating through them (e.g. terminology, nominalizations, notations, graphs, etc) (Halliday and Martin, 1996; Kress and van Leeuwen, 1996).

Classification and formality combined, determine the degree of 'scientificness' of a particular pedagogic discourse, since a discourse projecting the internal logic of the scientific content (strong classification) and employing its specialised expressive codes (high formality), clearly drives the students closer to the specialised scientific knowledge domain.

In specific, the combination of the two values that can be ascribed to classification with the two values that can be ascribed to formality (strong and weak) produces four different potential modalities of the science education pedagogic discourse, namely the esoteric, the metaphorical, the public and the mythical one (Dowling, 1994) (see Fig. 1).

The degree of 'scientificness' of the pedagogic discourse increases if one moves from the public (non specialized content and codes, e.g. newspapers' science) to the metaphorical (specialized content and non-specialized codes e.g. popular scientific magazines) and from there to the esoteric modality (specialized content and codes e.g. specialized journals). The mythical (specialized codes but non specialized content e.g. science fiction books) is a theoretically potential modality but it very rarely describes real pedagogical practices. For this reason the mythical modality will be excluded from further consideration within this paper.

	Strong Classification	Weak Classification
High formality	Esoteric	Mythical
Low formality	Metaphorical	Public

Figure 1

The pedagogic modalities projected in science textbooks and emerging from the combination of the levels of classification and formality

Finally, in every pedagogic discourse a social interaction between the addresser of subject-matter (teacher or textbook’s voice) and students is established. ‘Framing’ determines which side, the addresser or the students has the control over the pedagogic interaction (Bernstein, 1996). Strong framing means that the pedagogic control belongs clearly to the addresser while weak framing means that there is some space left to the students so as to exert their own control over the learning process.

Since the issue of the pedagogic control is heavily influenced by the social hierarchies established as well the degree that the pedagogic message can be negotiated by its addressees, the notion of framing can be conceptually further elaborated by referring to the dimensions of: a) the imposition of the addresser over the learners and b) the addresser’s control of the conditions for the learners’ involvement. Specifically, strong framing, as far as the imposition relationships is concerned, means that students are put in a powerless social position during the pedagogic process while weak framing means that they become empowered so as to exert their own control over the learning processes that takes place through the reading of the science textbooks. Furthermore, strong framing as far as the conditions for the students’ involvement is concerned, means that these conditions are fully pre-determined without the latter having any control over them. On the contrary weak framing means that the students have the potential for negotiating the conditions of their participation in the learning process (Bernstein, 1996).

Combining further, the dichotomized values of classification, formality and framing one can produce six modalities in order to describe the corresponding pedagogic practice (the mythical domain has been excluded from further analysis). These six modalities can be seen in a diagrammatic form in Figure 2. Specifically, the modality M1 corresponds to highly specialized content and codes but weak pedagogic control and could be named as *liberal esoteric* pedagogy, whereas M6 corresponds to non-specialized content and codes as well as strong pedagogic control and could be named *authoritarian public*. The first type of pedagogy could be projected for example in textbooks used in post-graduate academic studies where the students can be treated as knowledgeable young peers with significant degrees of freedom while the second type of pedagogy could be projected in text

materials used in a health education program for the general public where the main objective would be the provision in the form of strict guidelines and using non technical codes, of scientific knowledge that can be easily applied in the context of every day life.

Scientificness (Classification & Formality)	<i>Esoteric</i>	M1	M2
	<i>Metaphorical</i>	M3	M4
	<i>Public</i>	M5	M6
		<i>Weak</i>	<i>Strong</i>
Framing			

Figure 2

The pedagogic modalities emerging from the combination of classification, formality and framín

In this paper, the two dimensional mapping of the pedagogic modalities shown in Figure 2, will be used so as to describe the discursive transition of science subjects from primary to secondary education in Greece, at least as this transition is reflected by the use of the linguistic and the visual codes employed in the corresponding science textbooks of each level. This kind of analysis becomes possible taking into account that the ways that the linguistic and the visual mode are employed in the school science textbooks modulate the levels of classification, framing and formality and, hence, tend to position the students both in relation to the esoteric domain (specialised content and codes) of the corresponding specialised knowledge, and also as social subjects that take part in a pedagogical-communicative process. This function of the two expressive modes is realised by specific expressive conventions that act as resources for constructing specific pedagogic modalities.

Methodology

The texts analysed are taken from six science textbooks written in Greek and used in 9.823 Greek primary and secondary schools during 1997-1999 (the secondary textbooks are still in use). Specifically, these textbooks consist of: a) two general science textbooks for the two upper grades of primary school (11-12 year olds), b) two chemistry and c) two physics for the three grades of the lower secondary school respectively (13-15 year olds).

In order to implement our analytic plan, the textbooks were divided into units of analysis for both the linguistic and the visual mode. Specifically, in order to analyse the pedagogic modality projected by the linguistic mode, different genres within the textbooks were distinguished. These genres constitute the units of analysis. According to genre analysis (Martin, 1997; Cope and Kalantzis, 1993) a text differs in structure according to its purpose. The genres appearing in the Greek science textbooks are *reports*, *experimental accounts* and *historical accounts*.

‘Report’ is a type of text that describes how things are, presents information by building up generalisations, classifies various entities and explains processes in natural phenomena or explains how a technological artefact works. ‘Experimental

account' is a type of text that usually contains a series of sequenced steps, which show how a specific experimental task should be carried out, and/or presents the results of this task. Finally, 'historical account' is a type of text that presents either episodes from the history of science and technology or biographical information about famous scientists and engineers. In this way a total of 1153 units of analysis of the textbooks' linguistic mode were identified. Of these units 876 (76%) are reports, 205 (17.8%) are experiments and 72 (6.2%) are historical accounts.

On the other hand all the visual images contained in the six science textbooks were analysed. Any visual image in a distinct frame within the textbooks was considered as a single unit of analysis. Following this procedure, a sample of 2819 visual images was collected.

All the units of analysis for both the linguistic and the visual mode were analysed along the three theoretical dimensions of classification, formality and framing. The analysis was based on the use of two distinct grids of analysis, one for the linguistic and one for the visual mode, that consist of variables that become operational applying specific socio-linguistic and socio-semiotic approaches. Specifically, the basic underlying idea of the two grids is that certain lexicogrammatical and semiotic elements of the linguistic and visual mode respectively, modulate accordingly the levels of classification, formality and framing. For example while formality in the case of the linguistic mode was evaluated in terms of the density of: a) scientific notation (terms, symbols and equations), b) nominal groups, c) verbs in passive voice and d) sentences in hypotactic syntax, the same notion in the case of the visual mode is evaluated on the basis of the degree an image is characterized by: a) elements like geometrical shapes and alphanumeric strings, b) color differentiation, c) color modulation and d) background differentiation. The two grids of analysis have been extensively presented, together with informations about their limitations and reliability, in other publications of the authors (Koulaidis, Dimopoulos and Sklaveniti, 2002; Dimopoulos, Koulaidis and Sklaveniti, 2003).

Results

Below, the results of the textbooks analysis in terms of the pedagogic modalities promoted by their linguistic and visual expressive modes respectively of the textbooks analyzed, are presented.

The Linguistic Mode

The analysis of the school science textbooks of both primary and secondary level showed that the vast majority of their linguistic units belong to the metaphoric modality (strong classification and low formality). Specifically, as shown in Table 1, the discursive transition that seems to occur through the linguistic mode of the school science textbooks is that of a very gradual introduction of students to the specialized content and codes of scientific knowledge as they proceed from primary to lower secondary school. This transition, however, does not seem to be completed at the lower secondary level as the textbooks still employ a linguistic mode that mainly projects a metaphoric modality.

Table 1
The pedagogic modality (in terms of classification and formality) promoted by the linguistic mode of the school science textbooks of primary and lower secondary level

Pedagogic modality	Primary textbooks		Lower secondary level	
	N	%	N	%
Esoteric	14	7.7	173	17.8
Metaphoric	141	77.9	699	71.9
Public	26	14.4	100	10.3
Total	181	100	972	100

As far now as the level of framing projected by the linguistic mode of the school science textbooks is concerned, it was found that the primary textbooks are characterized by much stronger framing than the textbooks of the lower secondary level (see Table 2). In other words, the science textbooks used in the primary school allow a much narrower range of available options for students, so as to exert some control over the pedagogic process enacted by them, in comparison to the corresponding available range provided by the lower secondary level science textbooks. Thus, the science textbooks of primary level construct a social identity of students according to which, the latter are put in a subordinate social position and are highly directed towards the acquisition of the relevant subject-matter. On the contrary, the science textbooks of lower secondary level construct a social identity of students according to which these are highly autonomous learners who can access the relevant subject matter in their own ways.

Table 2
The level of framing promoted by the linguistic mode of the school science textbooks of primary and lower secondary level

Level of framing	Primary textbooks		Lower secondary level	
	N	%	N	%
Strong	87	48.1	26	2.7
Weak	94	51.9	946	97.3
Total	181	100	972	100

Combining further the results shown in Tables 1 and 2 respectively, and using the two dimensional representation of the pedagogic modalities introduced in Figure 2, the promoted by the linguistic mode of the school science textbooks discursive transition which it also corresponds to pedagogic transition from primary to lower school, can be mapped as shown in Figure 3.

Scientificness (Classification &Formality)	<i>Esoteric</i>		
	<i>Metaphorical</i>	Lower Secondary Level	<i>Primary Level</i>
	<i>Public</i>		
		<i>Weak</i>	<i>Strong</i>
Framing			

Figure 3

The transition across pedagogic modalities projected by the linguistic mode of the science textbooks of primary and lower secondary level respectively

The pedagogical message emerging from the transition shown in Figure 3 is that, as students become gradually more experienced in science (by being introduced to texts characterized by stronger classification and formality) they are increasingly allowed to experience more autonomous ways of negotiating the terms of their participation in the learning process (weaker framing).

The Visual Mode

The analysis of the visual images contained in the school science textbooks showed that the majority of these images in the primary textbooks correspond to the public modality (non specialized content and code or weak classification and low formality) while in the textbooks of the lower secondary school correspond to the metaphoric modality (specialized content but non-specialized code or strong classification but low formality). Specifically, as shown in Table 3, in the primary textbooks 62% of the visual images correspond to the public modality, but still a considerable percentage of 34.6% of them corresponds to the metaphoric modality. This situation is almost reversed in the science textbooks of the lower secondary level, where 55.7% of their images correspond to the metaphoric and 37.4% to the public modality respectively.

Table 3

The pedagogic modality (in terms of classification and formality) promoted by the visual mode of the school science textbooks of primary and lower secondary level

Pedagogic modality	Primary textbooks		Lower secondary level	
	N	%	N	%
Esoteric	49	3.3	92	6.9
Metaphoric	516	34.6	742	55.7
Public	922	62.0	498	37.4
Total	1487	100	1332	100

The results imply that the visual mode tend to play a similar role with the linguistic mode of the school science textbooks since both seem to function so as to gradually introduce students, as these move from primary to secondary school, into the more specialized discourses of scientific knowledge. This, in the case of the visual mode as shown in another study of (Dimopoulos, Koulaïdis and Sklaveniti, 2003), is accomplished by the use of more images incorporating the conventions of the techno-scientific graphical mode (conventional images and hybrids) and more images that seem to promote the conceptual re-organisation of the world like the analytical and the classificational ones, as the educational level rises.

It is also characteristic that especially in the primary school the visual mode is not so much employed so as to promote the conceptual understanding of the scientific content as to attribute a pre-eminent value to real world elements, the salience of which seems to be exploited as an (experiential) anchor to the introduction of students to the reified and highly abstract world of science (Dimopoulos, Koulaïdis and Sklaveniti, 2003).

With regards now to the level of framing promoted by the visual mode, it was found that the school science textbooks of both primary and lower secondary level promote a kind of social-pedagogic relationship characterized by weak framing (Table 4). In other words, the visual images of these texts create a sense of empowerment to their readers so as to maintain their own control in the communication-pedagogic process.

Table 4

The level of framing promoted by the visual mode of the school science textbooks of primary and lower secondary level

Level of framing	Primary textbooks		Lower secondary level	
	N	%	N	%
Strong	303	21.8	174	15.6
Weak	1085	78.2	943	84.4
Total*	1388	100	1117	100

* These totals correspond to realistic representations only

Combining further, the results shown in Tables 3 and 4 and using the two-dimensional mapping of the pedagogic modalities used in this paper (Figure 4), it can be concluded that as the educational level rises, the use of the visual mode is

transformed from a means to ground scientific knowledge to the every-day experiences of students (public modality) to a means of introducing the latter towards the specialized content of science (metaphorical modality). It is characteristic though that the visual mode during both phases of this transition contributes to the maintenance of the students' control over the pedagogic process. Therefore, the visual mode is an element of the school science textbooks that constantly enables students to access the relevant subject matter in their own independent ways.

Scientificness (Classification &Formality)	<i>Esoteric</i>		
	<i>Metaphorical</i>	Lower Secondary Level	
	Public	Primary Level <i>Weak</i>	<i>Strong</i>
<i>Framing</i>			

Figure 4

The transition across pedagogic modalities projected by the visual mode of the science textbooks of primary and lower secondary level respectively

Pedagogic Implications

As already mentioned in the introduction section, in this study school science textbooks are considered as means of regulating the pedagogic discourse of each of the educational levels they are used to and as a consequence as a mirror of the pedagogic transitions in science education that occur when moving from the primary to the lower secondary level.

Combining the results from the analysis of both the linguistic and the visual modes employed in the science textbooks of both levels, the discursive transition that emerges is from the metaphoric-authoritarian towards the metaphoric-esoteric or metaphoric-liberal modality.

In other words the main pedagogic transitions that occur as the educational level rises are primarily the weakening of the pedagogic control and, secondarily an increase in the formality of the linguistic code employed (gradual move towards the esoteric modality). The latter transition is still moderate and remains uncompleted even in the textbooks of the last class of the lower secondary school (age level 15-16 years old).

The pedagogic position projected by this picture is, then, that as science students progress through the specialised knowledge domain, they become more capable of processing the textbooks' message in more individualistic and

autonomous ways. In other words, the lower secondary textbooks treat students as independent learners that have control over how they learn and so they do not feel intimidated by the pace and the ways the textbooks deliver the relevant subject matter. A similar to above differentiation between the educational levels, as far as the projected independent mode of learning, was also found in an extensive study of 187 school physics textbooks in the US, which followed a different perspective from ours (Mulkey, 1987).

The trend imposed by the science textbooks of a gradual move towards more specialised forms of scientific knowledge (both content and codes specialised) with a parallel increase in the students' autonomy in determining how to access the relevant text material is in distinct opposition to the widely held pedagogic position, very often translated into teaching practice, which favours more guidance and fewer opportunities for initiative on the part of the learner as the school subjects become more academic and content-specialised (Cazden, 1988; Edwards and Westgate, 1987; Rodrigues and Bell, 1995).

Additionally, the trend of reduced 'guidance' of students through the lower secondary level textbooks and the parallel increase in the relevant subjects' specialisation, are in conflict from a pedagogic point of view. This conflict is based on the assumption that it is exactly when the specialisation of a school subject increases that students need more guidance and support for its acquisition. This discursive conflict could potentially explain the effects of disorientation and lack of ability to focus on the important pieces of information experienced by many students at this level (and especially the less competent) while trying to make meaning out of the relevant textbooks (Yore, Craig and Maguire, 1998; Alexander and Kulikowich, 1994; Patterson, 2001; Keys, 1999).

Furthermore, the comparison between the pedagogic modalities emerged by the linguistic and the visual mode of the science textbooks respectively, reveals that the visual mode tends to lower both the classification and the formality of the relevant texts. In this way though, by not being exposed to the conventions of the techno-scientific images students may be excluded from 'seeing' and 'processing' reality in a similar way with the experts (Lynch, 1985; Trumbo, 1999). On the other hand the visual mode tends to relate more to the public modality and hence it becomes much more in comparison to the linguistic mode the vehicle for relating the every-day experiences of students with the scientific knowledge.

Closing this paper, it should be pointed out that the framework presented here allows the development of a common theoretical language so as to describe the pedagogic modalities projected by school science textbooks as well as by many other educational materials employed in science education. The functional knowledge of this theoretical language would enable both the authors of science textbooks and the teachers that use them to become much more reflexive about their pedagogic implications.

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