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Towards an Analysis of Visual Images in School Science Textbooks and Press Articles about Science and Technology

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Abstract

This paper aims at presenting the application of a grid for the analysis of the pedagogic functions of visual images included in school science textbooks and daily press articles about science and technology. The analysis is made using the dimensions of content specialisation (classification) and social-pedagogic relationships (framing) promoted by the images as well as the elaboration and abstraction of the corresponding visual code (formality), thus combining pedagogical and socio-semiotic perspectives. The grid is applied to the analysis of 2819 visual images collected from school science textbooks and another 1630 visual images additionally collected from the press. The results show that the science textbooks in comparison to the press material: a) use ten times more images, b) use more images so as to familiarise their readers with the specialised techno-scientific content and codes, and c) tend to create a sense of higher empowerment for their readers by using the visual mode. Furthermore, as the educational level of the school science textbooks (i.e., from primary to lower secondary level) rises, the content specialisation projected by the visual images and the elaboration and abstraction of the corresponding visual code also increases. The above results have implications for the terms and conditions for the effective exploitation of visual material as the educational level rises as well as for the effective incorporation of visual images from press material into science classes.

Key Words: classification, formality, framing, press articles, school science textbooks, visual images

Two of the most important text forms through which science and technology are communicated to non-specialised publics are school science textbooks and press articles. The latter form in particular, plays an increasingly significant role in presenting science and technology to non-experts since the relevant proportion of the press coverage has been considerably increased over the last two decades (Bader, 1990; Bucchi, 1998; Nelkin, 1995), contributing to the shaping of the public mind on these issues (Elliott & Rosenberg, 1987; Gamson & Modigliani, 1989; Hornig Priest, 1995).

These texts, contrary to widely held beliefs, are not mere simplified versions of the texts of the techno-scientific primary literature as implied by terms like popularisation, dissemination and diffusion; on the contrary, they constitute a re-contextualisation of the corresponding knowledge according to the organising principles, prevailing conventions and legitimate ideologies of each communicative-institutional context (school and mass media in our case) (Bernstein, 1996). One of the means by

which the techno-scientific texts for non-specialists accomplish this re-contextualisation is the discursive interplay of a variety of available modes as potential resources for meaning making in them. Among such modes a significant one is the visual mode (Jacobi, 1999; Kress & van Leeuwen, 1996; Lemke, 1998) and despite the fact that we believe that it is exactly the inter-play of the visual images with the written text that contributes to the expansion of the meaning making potential of the texts (Koulaidis, Dimopoulos, & Sklaveniti, 2002), in this paper we will focus only on the analysis of the visual images of school science textbooks and articles published in the press.

The autonomous analysis of the visual mode is considered essential for the following reasons. Firstly, there has been a shift in the cultural significance attributed to the visual over the linguistic aspects of the non-specialised techno-scientific texts due to a growing number of new technologies that facilitate the creation of captivating images and the fact that visualisation of science and technology is ubiquitous, from the World Wide Web up to science-oriented advertisements (Kress & van Leeuwen, 1996; Messaris, 1994; Trumbo, 1999). This shift has definitely influenced modern science textbooks, which use many more visual images compared to the past, in order to communicate their content to students (Bazerman, 1988; Kress & van Leeuwen, 1996; Myers, 1995). Despite this situation, the analysis of the visual images of the techno-scientific texts for non-specialists is the poor relation in the relevant research area. This means that although the written language has been analysed quite extensively (Bazerman, 1988; Halliday, 1996; Lemke, 1993; Myers, 1990a) the corresponding research about the visual images of such texts is rather poor and fragmented (Jacobi & Schiele, 1989; La Follette, 1990; Myers, 1990b; Veel, 1998). Specifically, a literature review concerning science textbook analysis in the ERIC database for the period 1985–2002, revealed 222 relevant studies. By these studies, 13% focused on the analysis of the written language (vocabulary, rhetoric) of the textbooks while only 2% focused on the visual images contained in them. The same applies for the press. Specifically, among 57 relevant studies conducted during the last two decades, only two analysed the visual images of press articles. It is therefore evident that there is a need for a more systematic research effort concerning the visual aspects of these texts.

Secondly, furthermore, contrary to the deep seated cultural positions that it is in the language that messages and meanings primarily reside and that a visual illustration is a relatively transparent and unproblematic window to reality, we adopt the position that visual images are autonomous systems of communication that do not simply reproduce reality but produce images of reality which are bound up with the interests of the social institutions (school and mass media) within which the pictures are produced, circulated and read (Kress & van Leeuwen, 1996). This approach resists the naïve realism that considers each visual image as a message without syntax and replaces it with the position that the visual images have specific conventions embedded in their construction. These conventions operate in such a way so as to reconfigure the semantic content of the illustrations and hence to create specific types of order, relations and identities within the pedagogic and the more general communicative discourse.

Thirdly, and finally, students seem to assess the visual images of science textbooks in a rather independent way from the written text (Pinto & Ametller, 2002). Furthermore, the implicitness of the visual syntax seems to cause serious difficulties in the interpretation of the visual images by the students, difficulties of which most science teachers seem to be completely unaware (Leinhardt, Zaslavsky, & Stein, 1990; Pinto & Ametller, 2002).

This analysis will present a grid for analysing the pedagogic functions that become possible by specific discursive re-arrangements of the visual images in the corresponding texts and its application in the case of school textbooks and press articles.

The findings of such an analysis can form the basis for a better understanding of the pedagogic functions of the visual mode. In order to describe the pedagogic functions of the visual images, we use the notions of classification, framing (Bernstein, 1996) and formality (Halliday, 1996).

Classification determines the epistemological relationship between knowledge categories (Bernstein, 1996). In the case of our paper, the categories examined are the specialised 'techno-scientific knowledge' and the 'everyday knowledge.' Strong classification formulates well-defined borderlines between techno-scientific knowledge and everyday knowledge, that is, the contents of these categories are clearly segregated while weak classification results in vague or blurred borderlines between them.

Framing refers to the controls on communication established by the texts (Bernstein, 1996). In other words, framing regulates the social relations in a context of communication. Strong framing means that the control belongs clearly to the addresser while weak framing means that there is some apparent space left to the addressee (student) so as to exert his/her own control over this process. The issue of the pedagogic control is heavily influenced by the social hierarchies established as well as the degree that the pedagogic message can be negotiated by its addressees. Therefore the notion of framing can be conceptually further elaborated by referring to the dimensions of: a) the imposition of the addresser over the addressee, and b) the addresser's control of the conditions for the addressee's involvement. Specifically, strong framing, as far as the imposition relationships are concerned, means that the addressee (student) is found in a powerless social position during the pedagogic process while weak framing means that he/she becomes empowered so as to exert his/her own control over the communication process that takes place in the science classes. Furthermore, strong framing as far as the conditions for the addressee's involvement is concerned, means that these conditions are fully predetermined without the student having any control over them while weak framing means that the addressee (student) has the potential for negotiating them.

Finally, formality corresponds to the degree of abstraction, elaboration and specialisation of the expressive codes employed. Low formality corresponds to codes resembling very much the vernacular ways of expression or lying very close to the realistic appearances of things. On the other hand, high formality corresponds to specialised codes that define reality in terms of abstractions and deeper regularities.

The discursive elements of the visual images tend to modulate the levels of classification, framing and formality and hence to position their viewers both in relation to the interior of the corresponding specialised knowledge domain and also as social subjects that take part in a specific pedagogical process.

Methodology

The visual images analysed are those of: a) six mandatory science textbooks, which are used in all the 9,823 Greek primary and secondary schools during the school years 1997–1999 (the secondary textbooks are still in use), and b) 1867 press articles published during the period 1996–1998 in four Greek newspapers of national outreach and broad readership. Specifically, all the images contained in the six science textbooks were analysed. The six textbooks consist of two general science textbooks of the last two grades of primary school (age level 11–12 years old) and two chemistry and two physics textbooks of the two last grades of the lower secondary school respectively (age level 14–15 years old). We concentrated on the textbooks of the primary and the lower secondary level because these two constitute the levels of compulsory education in Greece.

Additionally, a sample of 1867 articles about science and technology were selected from the four newspapers "Vima" ("Forum"), "Eleftherotypia" ("Freedom of the Press"), "Eleftheros Typos" ("Free Press") and "Kathimerini" ("Daily"). The criteria for selecting these four newspapers were: (a) their national outreach, (b) their broad readership (the overall circulations of all four newspapers accounted for the 35 percent of the total readership of the dailies and the 65 percent of the total readership for Sunday newspapers in Greece over the period of the study), (c) the representativeness of their political orientation ("Eleftheros Typos" and "Kathimerini" are considered conservative, while "Vima" and "Eleftherotypia" are considered liberal newspapers), and (d) the fact that all contain special sections about science and technology.

The sampling procedure used for the press material was that of the 'constructed week' (Hansen, Cottle, Negrine, & Newbold, 1998). By the term constructed week we mean a series of seven week-days (one Monday, one Tuesday, and so forth), which correspond to randomly selected non-consecutive dates. In particular, for each newspaper, four constructed weeks per year of the period examined in this study (1996–1998) were selected.

Following this procedure, a sample of 2819 visual images were collected from the six school science textbooks and another 1630 images were additionally collected from the press. These images were analysed using three dimensions. The first dimension concerns all the elements involved in their syntactic construction that denote the degree of their content specialisation (classification).

The second dimension corresponds to the social-pedagogic relationships that tend to be established between the message of the images and their viewers (framing). This second dimension is further subdivided into two finer dimensions, one addressing the issue of the imposition relationships established by the reading of each

Figure 1: Realistic image (Georgiadou, T. et al. (1997). *Chemistry for lower secondary school (Grade B)*. Athens, Greece: OEDB, p. 88).

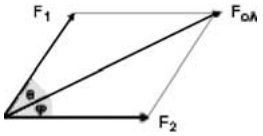


Figure 2: Conventional image – "Resultant force" (Karapanagiotis, B. et al. (1998). *Physics for lower secondary school (Grade B)*. Athens, Greece: OEDB, p. 134).

image and another corresponding to the degree an image prompts its viewers to actively participate in the processing of the visual meaning (e.g., thorough observation, imaginary handling, etc.).

Finally, the third dimension corresponds to the degree of abstraction characterising the techno-scientific images (i.e., formality of the visual code). These three dimensions consist of variables that become operational applying a specific socio-semiotic analysis of the grammar of their visual design. Our socio-semiotic analysis follows the work done by Kress and van Leeuwen (1996).

Classification

The content specialisation (classification) of the visual images is assessed using the variables of their: a) type and b) function. With regard to their type, the visual images can be characterised as realistic, conventional and hybrids. All the visual images that represent reality according to human optical perception are considered as realistic (Figure 1). In this category belong both photographs and drawings.

All the visual images that represent reality in a codified way are considered as conventional (Figure 2). These representations which are usually graphs, maps, flowcharts, molecular structures and diagrams, are constructed according to the techno-scientific conventions and are important to the scientific writing (Lynch, 1990) since (a) they constitute the best tools to represent covariation between continuous measures (Lemke, 1998), (b) are useful to condense large amounts of data in economical

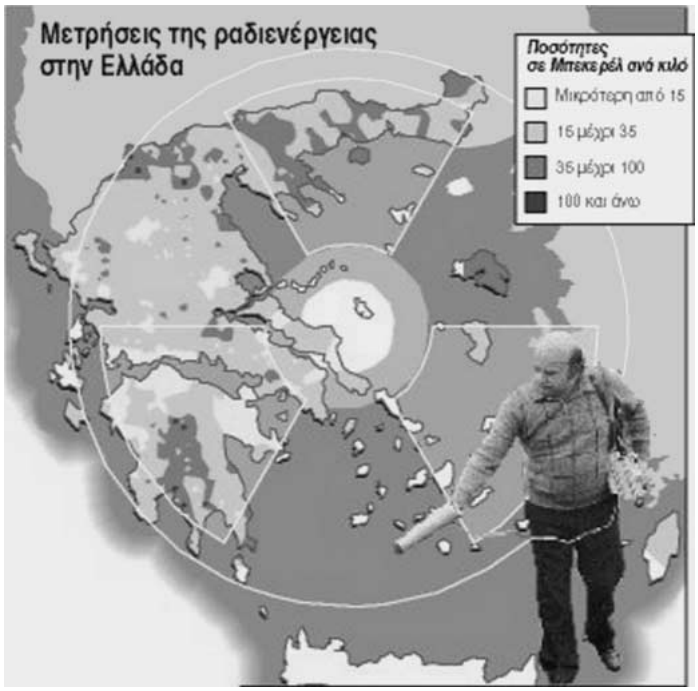
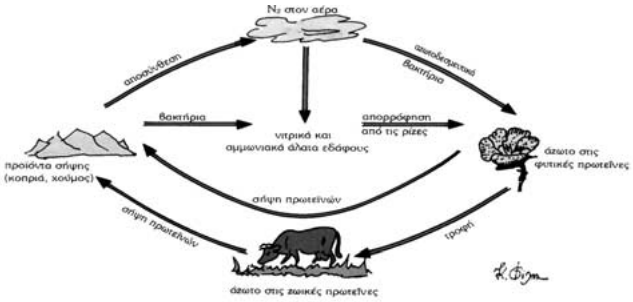


Figure 3: Hybrid. "Measurements of radioactivity in Greece" ("Vima" (15/11/1997)).

ways (Latour, 1987), and c) are instrumental in reinforcing the ontological stability of processes and entities of the reified techno-scientific world (Gross, 1996).

Finally, hybrids include all the images in which elements from both the above two types (realistic and conventional) co-exist. These are usually conventional representations with added on realistic features. In this way the conventional nature of these representations is moderated by the appearance in them of naturalistic figures (Figure 3). From the analysis above it follows that the conventional images correspond to strong, the hybrids to moderate and the realistic to weak classification.

Furthermore, the visual images according to their function are divided into narrative, classificational, analytical and metaphorical representations. Narrative representations are those that represent "unfolding actions and events, processes of change and transitory spatial arrangements" (Kress & van Leeuwen, 1996, p. 56). In this kind of image the represented action is visualised by a vector either shown explicitly or imaginarily implied (e.g., the directionality of a man's hand about to throw a stone corresponds to an imaginary vector). Narrative representations are usually used in the examined techno-scientific texts in order to illustrate technical (e.g., experimental procedures) or natural processes (e.g., nitrogen cycle in nature, Figure 4). The linguistic equivalent of narrative representations is that of the action verbs.



Translation of the captions

προϊόντα σήψης (κοπριά, χούμος)=degradation products (humus)
αποσύνθεση=degradation
N_2 στον αέρα=N_2 in the air
αποικοδομητικά βακτήρια=degradative bacteria (decomposers)
νιτρικά και αμμωνιακά άλατα εδάφους=soil ammonium and nitrate
απορρόφηση από ρίζες=root absorption
άζωτο στις φυτικές πρωτεΐνες=nitrogen in plant proteins
άζωτο στις ζωϊκές πρωτεΐνες=nitrogen in animal proteins
σήψη πρωτεϊνών=protein degradation

Figure 4: Narrative image – "The nitrogen cycle in nature" (Georgiadou, T. et al. (1997). *Chemistry for lower secondary school (Grade B)*. Athens, Greece: OEDB, p. 93).

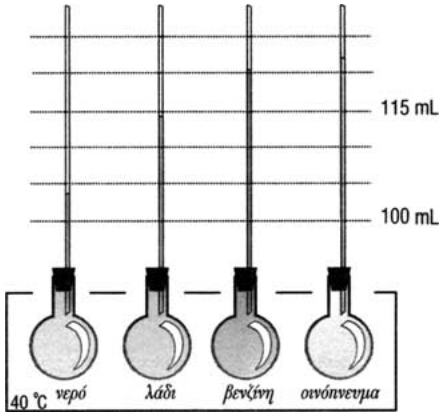
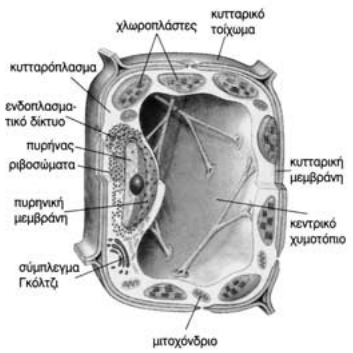


Figure 5: Classificational image – "Volume expansion of different liquids" (Karapanagiotis, B. et al. (1998). *Physics for lower secondary school (Grade B)*. Athens, Greece: OEDB, p. 83).

Classificational images are those that exhibit types of relationships between the people, places and things presented in them or to put it differently, a taxonomy. A group of represented agents plays the role of subordinates with respect to one other represented agent, the super-ordinate. The super-ordinate may be either explicitly shown in the illustration, or indicated in the accompanying text or even inferred by the viewer according to his/her own experience. The proposed equivalence between the subordinates is usually visually realised by a symmetrical composition (Figure 5).



Translation of the captions

κυτταρόπλασμα=cytoplasm
ενδοπλασματικό δίκτυο= endoplasmic reticulum
πυρήνας=nucleus
ριβοσώματα=ribosomes
πυρηνική μεμβράνη=nuclear membrane
σύμπλεγμα Golgi= Golgi apparatus
μιτοχόνδριο=mitochondrion
κεντρικό χυμοτόπιο=central vacuole
κυτταρική μεμβράνη=cell membrane
κυτταρικό τοίχωμα=cell wall
χλωροπλάστες=chloroplasts

Figure 6: Analytical image – "The structure of a plant cell" (Gelti-Douka, E. et al. (1999). *Biology for Lower Secondary School (Grade C)*. Athens, Greece: OEDB, p. 23).

Such images are used in techno-scientific texts when the objects of the natural world are to be represented in terms of a hierarchical order and when the main concern of the text is the ranking of phenomena from the perspective of a single unifying term. The linguistic equivalents of classificational images are expressions like 'this belongs to' or 'this is the kind of.'

Analytical images are those that focus on the relationships between the objects of representation in terms of a part-whole structure (Figure 6). The parts of the whole may be labeled or it may be left up to the viewer to do so. As a whole, an analytical image is the most elementary option and its meaning corresponds to the linguistic equivalents 'this is' or 'this consists of.'

Finally, metaphorical images are those that "connote or symbolise meanings and values over and above what they literally represent" (Kress & van Leeuwen, 1996, p. 45). The represented participants in these images are conventionally associated with specific cultural symbols. For example, Figure 7 below represents Celsius to demonstrate a thermometer. The posture of Celsius as well as his formal way of dressing (typical dress of a noble man of the eighteenth century), can act as metaphors of the high social status of scientists and more generally of science.

Furthermore, whenever techno-scientific texts employ realistic visual images these are mainly analytical and classificational ones. Specifically, techno-scientific texts employ images that represent the various entities still with all the details of their appearances suppressed (Lynch, 1990) so that they can be scrutinised in detail and become dissected into their parts (Halliday, 1996). These images are the analytical ones according to our grid of analysis. Morever, techno-scientific texts frequently employ classificational images according to Amann and Knorr Cetina (by being) "carefully edited montages assembled from fragments of other images" (1990, p. 112), re-organise the relationships between the natural entities so as to build up new theoretical descriptions of the world. Therefore, analytical and classificational

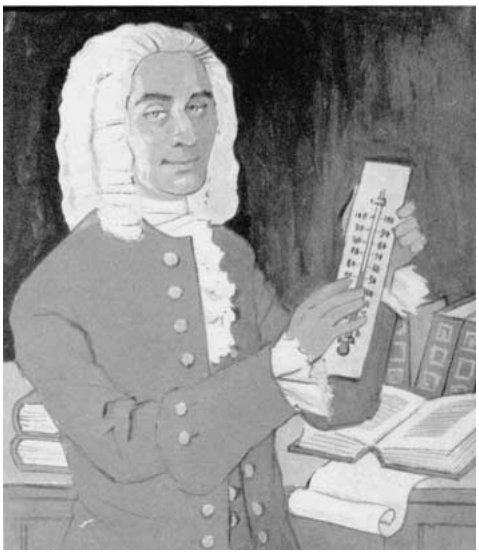


Figure 7: Metaphorical image – "Celsius and thermometer" (Alexopoulos, B. et al. (1989). *Science for primary school*. Athens, Greece: OEDB, p. 55).

images belong to the techno-scientific ways of representing things and hence they promote strong classification.

Combining the results of the above two variables of type and function, one can estimate the degree of the content specialisation promoted by visual images (classification). The images promoting strong classification hence building up strong boundaries between the specialised techno-scientific knowledge and every day knowledge are those which are conventional or hybrids and at the same time analytical or classificational. Conversely, the images characterised by weak classification are the realistic and the narrative or metaphorical ones. All the other combinations correspond to moderate classification.

Framing

Framing can be estimated by the elements of the visual syntax that tend to modulate the social positions of students during the communication procedure. These elements refer to both the imposition relationships and the degree of the viewer's involvement established during the relevant process. The more students are treated as social subjects having social power and being able to get actively involved in the pedagogic procedure the weaker the framing. Therefore, in order to operationalise the imposition relationships that tend to be established between images and viewers (first dimension of framing), we use the variable of the vertical angle of shot. The vertical angle of shot represents visually exactly these imposition relationships.

(a) Strong framing (low angle) ("Eleftheros Typos" (6/3/2000))

(b) Moderate framing (eye level) ("Eleftherotypia" (7/10/2000))

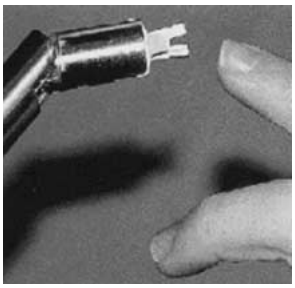
(c) Weak framing (high angle) ("Kathimerini" (5/11/2000))

Figure 8.

Specifically, if an image is shown from a low angle, this depicts a relationship in which the content of the image imposes over the viewer and hence the framing is strong (Figure 8a). If an image is shown at the eye-level of the viewer, this depicts a relationship in which the content of the image has equal power with the viewer and hence the framing is moderate (Figure 8b). Finally, if an image is shown from a high angle, this depicts a relationship in which the viewer imposes over the content of the image and hence the framing is weak (Figure 8c).

Furthermore, the degree of the viewer's virtual involvement with the images as a measure of his/her potential to participate is visually realised by the distance and the horizontal angle of shot. More particularly, the distance of the shot regulates the level of intimacy that is possible to be established between the projected meaning of an image and the viewer, and takes the values of close, medium and distant shot that correspond to an intimate/personal, social and impersonal relationship respectively (Meyrowitz, 1986). Close is defined as any shot that shows objects as if the viewer is engaged with them, that is, as if he/she is using an apparatus, smelling a chemical substance or reading a map. In cases where a person is represented the close shot corresponds to an image that shows head and shoulders of the subject. Medium is defined as any shot that shows objects in full but without much space around them, signifying in this way that these objects are within the viewer's reach, but not as actually used. Where a person is represented the medium shot corresponds to an image where the subject is cut off at the knees. Finally, distant is defined as any shot that shows objects as if they are there for the viewer's contemplation only and out of his/her own reach. When a person is represented the distant shot corresponds to an image where the subject occupies about half the height of the frame or anything less than that (Kress & van Leeuwen, 1996).

The horizontal angle of shot signifies the degree of familiarity that the viewer can have with the content of an image and takes the values of frontal and oblique angle. "The difference between the frontal and the oblique angle is the difference between



(a)

Weak framing ("Vima" (30/8/1998))

(b)

Moderate framing ("Vima" (20/12/1998))

(c)

Strong framing (Georgiadou, T. et al. (1998). *Chemistry for lower secondary school (Grade C)*. Athens, Greece: OEDB, p. 144.)

Figure 9.

familiarity and detachment" (Kress & van Leeuwen, 1996, p. 143). The message of the frontal angle is that "what you see here is part of your world, something you are familiar with" while the corresponding message of the oblique angle is that "what you see here does not belong to your world, it is something exotic that you are not familiar with."

The combination of the values of the two previous variables (distance and horizontal angle of shot) determines the overall value of the framing as far as the degree of the viewer's virtual involvement with the images is concerned. In particular, visual images characterised by frontal angle and close or medium shot are considered as corresponding to maximum level of involvement (weak framing) (Figure 9a) while those characterised by either frontal angle and distant shot or oblique angle and close shot are considered as corresponding to moderate level of involvement (moderate framing) (Figure 9b). Finally, representations characterised by oblique and medium or distant shot are considered as corresponding to minimum involvement (strong framing) (Figure 9c).

Since framing determines the social positions of students in terms of both the imposition and the degree of involvement (intimacy) they are allowed, the combination of the values for both dimensions gives an overall estimate of framing. Specifically, the combination of framing in terms of imposition relationships with framing in terms of the students' degree of involvement (intimacy) gives an overall strong framing if both these dimensions are characterised by strong framing, weak if both are characterised by weak framing and moderate in all other cases.

Formality

Finally, the formality of the visual code corresponds to the degree of its abstraction. The more an image represents the deeper essence of what it depicts by downgrading the superficial variability of its external features the higher is its formality. This is accomplished in scientific texts by using illustrations of reduced articulation (Kress & van Leeuwen, 1996; Lynch, 1990; Miller, 1998). Low formality then corresponds to representations very close to photographic realism while high formality corresponds to techno-scientific realism that defines reality in terms of what things are like generically or regularly.

The formality of the visual images can be estimated using relevant markers. These markers record particular constitutive elements of the representations that contribute to their level of abstraction (degree of articulation). Each marker may take three values: the maximum value (3) corresponds to high formality, the minimum value (1) to low formality and the sum of the values of all these markers gives an overall score for formality. In our analysis, the overall formality scores are transformed into three values: high, moderate and low. The markers used to evaluate the formality of the visual representations are:

1. *Elements of the techno-scientific code*: This marker concerns the existence of geometrical shapes or alphanumeric strings in visual representations. The appearance of such elements raises the formality of the visual representations.
2. *Color differentiation*: This marker is related to the variety of colors present in an illustration. The broader the variety of colors the lower the formality.
3. *Color modulation*: This marker corresponds to the degree of modulation of each color in the representation. Low formality corresponds to many different shades of a color while high formality corresponds to plain, unmodulated colors.
4. *Contextualisation*: This marker concerns the background of an image. High formality means the absence of any background while low formality means a fully articulated and detailed background.

If these four markers are applied to the three images of a simple electric circuit (Figure 10) then it becomes clear that the formality increases from the left circuit to the right circuit.

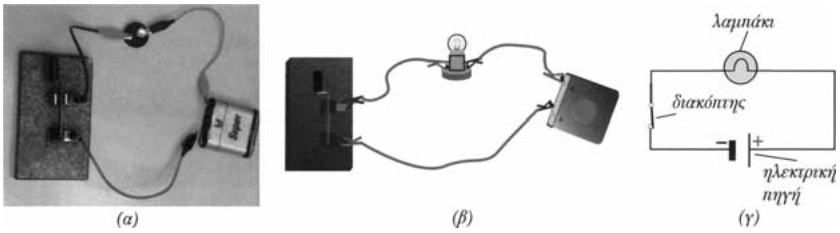


Figure 10: Formality rises from left to right circuit (Karapanagiotis, B. et al. (1998). *Physics for lower secondary school (Grade B)*. Athens, Greece: OEDB, p. 242).

Table 1 presents an overall view of our grid of analysis, showing the markers of all three dimensions used in this paper (classification, framing and formality) as well as the way of their assessment.

Finally, our grid was peer validated by two groups of educationalists. The first was a group of researchers working in the department of Education of the University of Cyprus whereas the second group consists of researchers working within the Greek Environmental and Education Center 'Gaia.' Specifically, these two groups were given the same two hundred and fifty images accounting for almost 9% of the total number of the images from school science textbooks and were asked to classify them applying our grid. The results have shown a 90% inter-coder agreement. This exercise was part of the familiarisation of the two groups with the grid, which was subsequently adopted and applied to the analysis of the Cypriot school science textbooks and the images contained in the exhibits of the 'Gaia' Center (Koulaidis, Dimopoulos, & Matiatos, 2002; Koulaidis, Dimopoulos, & Sklaveniti, 2002).

Results

Below, we present the results of our analysis concerning: a) the relative density of the visual illustrations (number of images/1000 words), b) the distinction between expert and every-day knowledge (classification) promoted by the visual images of the texts, c) the social-pedagogical relationships implied by these images (framing), and d) the degree of elaboration and specialisation of the corresponding visual code (formality). Specifically, we are going to compare school science textbooks with press material and also the textbooks of primary with those of lower secondary level along the four aforementioned dimensions (density, classification, framing and formality).

Density

The visual images constitute a considerable part of the communication of techno-scientific messages to non-experts since both school science textbooks and the press material analysed, contain a considerable number of them with the textbooks deploying this channel of communication much more than the press. More specifically, the average density of visual images in school science textbooks is almost tenfold compared with the press that is 11.1 images/1000 words whereas the corresponding density for the press is 1.2 images/1000 words.

The density distribution of visual images in school science textbooks is not constant across the different grades. As shown in Figure 11, it is drastically reduced as the educational level rises (the average density for Grade 5 of the Primary School is 19.8 images/1000 words while for Grade 3 of the Lower Secondary School it falls to 7.4 images/1000 words).

Table 1
The Grid of Analysis.

	Formality of visual images		
Markers of classification	**Strong**	**Moderate**	**Weak**
Type of visual image	Conventional	Hybrid	Realistic

	Strong	**Weak**
Function of visual images	Classificational, Analytical	Narrative, Metaphorical

Markers of framing	**Strong**	**Moderate**	**Weak**
Vertical angle of shot	Low angle	Eye-level	High angle
Distance of shot	Distant	Medium	Close

	Strong	**Weak**
Horizontal angle of shot	Oblique	Frontal

Markers of formality	**High**	**Moderate**	**Low**
Elements of techno-scientific code	Geometrical shapes and alphanumeric strings	Geometrical shapes or alphanumeric strings	Absence of any geometrical shapes or alphanumeric strings
Color differentiation	Monochrome	2–4 colors (black included)	More than 4 colors
Color modulation	No shade	1–3 shades	All the shades picked up by the photographic lens
Contextualisation	Background of the same color as the rest of the page	Mono or bi-chromatic background	Background according to the photographic realism

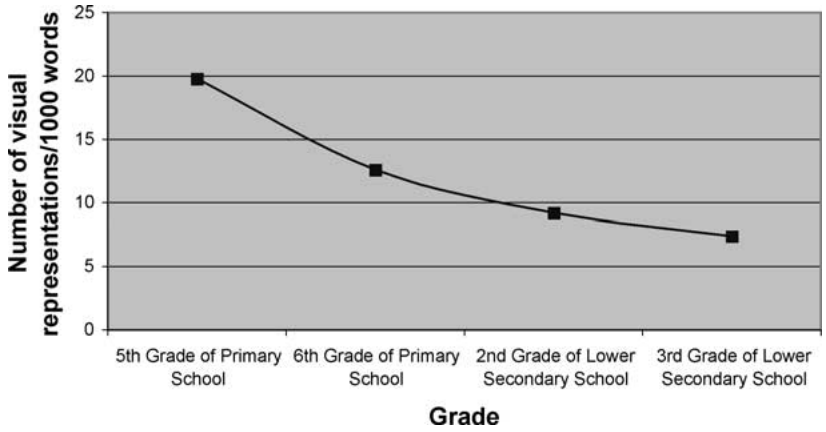


Figure 11: Density of visual representations in the school science textbooks by Grade.

Table 2
The Type of Visual Images in the School Science Textbooks and the Techno-scientific Articles of the Press.

Type of visual representations	Frequency (percentage) in textbooks	Frequency (percentage) in press
Realistic	2505 (89.0%)	1420 (87.1%)
Conventional	196 (6.9%)	110 (6.8%)
Hybrids	118 (4.1%)	100 (6.1%)
Total	2819	1630

The Distinction Between Expert and Every-day Knowledge (Classification)

The type of visual images

The visual images contained in both the school science textbooks and the press, are mainly realistic (89.0% in the textbooks and 87.1% in the press) while the conventional and hybrid images are far more rare (Table 2).

This result indicates that both forms of texts basically use the visual mode so as to attribute a pre-eminent value to real world elements, the salience of which seems to be exploited as an anchor to the introduction of students to the reified and highly abstract world of science. On the contrary the lack of many images that contain elements requiring appropriate readings of symbols (conventional images and hybrids) does not seem to contribute to the familiarisation of students with the

Table 3
The Type of the Visual Images of the Primary and Lower Secondary School Science Textbooks.

Type of visual representations	Frequency (percentage) Primary school	Frequency (percentage) Lower secondary school
Realistic	1388 (93.3%)	1117 (83.8%)
Conventional	56 (3.8%)	140 (10.5%)
Hybrids	43 (2.9%)	75 (5.6%)
Total	1487	1332

visual-graphical conventions experts use. This situation though, seems to change with the years of schooling since the science textbooks of the lower secondary school contain almost two and a half times more conventional representations and hybrids in comparison with the corresponding primary school textbooks (16.1% and 6.7% respectively) (Table 3).

The function of the visual images

As far as the function of the visual images is concerned, as shown in Table 4 the majority of them in both school science textbooks and press articles are analytical (61.8% in the textbooks and 52.9% in the press). This result suggests that the visual representations are quite frequently employed in techno-scientific texts for non-specialists as a means of exposing lay readers to the structure and the physical appearance of various entities (the virtual witnessing effect). However, as evidenced by Table 4, press articles contain many more metaphorical images than school science textbooks (28% and 2.8% respectively) thus lowering the content specialisation (i.e., classification) projected by the visual mode in this medium. The same trend is further reinforced by the fact that school science textbooks contain almost five times more classificational images than press articles (Table 4). An interpretation of this difference could be that the role of the school science textbooks is to bring their readers closer to the interior of the specialised techno-scientific knowledge domain whereas press material aims more at relating science and technology with broader social and cultural concerns.

The comparison between textbooks at the two educational levels examined here (primary and lower secondary level), as far as the visual functions are concerned, revealed that in both levels the visual images seem to play a strikingly similar role being mainly analytical and secondarily narrative in nature with the other two types of images (metaphorical and classificational) practically being very rarely met (Table 5).

Table 4
The Function of the Visual Images of the School Science Textbooks and the Techno-scientific Articles of the Press.

Function of visual representations	Frequency (percentage) in textbooks	Frequency (percentage) in press
Narrative	690 (24.5%)	272 (16.7%)
Classificational	293 (10.4%)	40 (2.4%)
Analytical	1742 (61.8%)	862 (52.9%)
Metaphorical	94 (3.3%)	456 (28.0%)
Total	2819	1630

Table 5
The Function of the Visual Images of the Primary and Lower Secondary School Science Textbooks.

Function of visual representations	Frequency (percentage) Primary school	Frequency (percentage) Lower secondary school
Narrative	382 (25.7%)	302 (22.7%)
Classificational	129 (8.7%)	99 (7.4%)
Analytical	958 (64.4%)	879 (66.0%)
Metaphorical	18 (1.2%)	52 (3.9%)
Total	1487	1332

Combining the results of the two variables of type and function of visual images in school science textbooks and the press, it could be concluded that these images portray techno-scientific knowledge as being much closer to the every-day common-sense experience rather than to the body of experts' knowledge. This conclusion is based on the finding that most visual representations are realistic and analytical hence promoting a particular emphasis on the physical appearance of things.

In relation to the classification dimension of our analysis, we conclude that the classification implied by the visual parts of both kinds of texts (school science textbooks and press articles) examined here is weak. The visual images of the school science textbooks and especially those of the lower secondary level, tend to project an image of techno-scientific knowledge as more specialised and distinguished from every-day experience. This is accomplished by the use in these science textbooks of more images incorporating the conventions of the techno-scientific graphical mode

Table 6
The Imposition Relationships between the Content of the Images and the Viewers in the School Science Textbooks and the Press.

Imposition relationships	Frequency (percentage) in textbooks	Frequency (percentage) in press
Viewer's imposition	1641 (65.5%)	291 (20.5%)
Equality	709 (28.3%)	1010 (71.1%)
Imposition of what is represented	155 (6.2%)	119 (8.4%)
Total	2505*	1420*

*These totals correspond to the realistic representations only.

(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. Summarising, we could say that the distinction between expert and every-day knowledge (classification) seems to become more marked from press to school science textbooks and from primary school to lower secondary school.

The Social-pedagogical Relationships Implied by the Visual Images (Framing)

The imposition relationships

The power distribution potentially established by the visual images in the school science textbooks is clearly skewed towards the viewer's side since in 65.5% of them the viewer seems to have imposition over the reading of the image (high angle shot) and in 28.3% the viewer is equal in power with the content of the images (shot at eye-level) whereas in only 6.2% the viewer is placed in a powerless position in relation to this content (low angle of shot) (Table 6).

On the other hand, in the press, in 71.1% of the illustrations the viewer is in a position of equality when viewing the content of the representations, while 20.5% depict a powerful position and only 8.4% depict a powerless position of the viewers.

It follows then that the images in the school science textbooks tend to be representative of a specific social type of student that feels powerful adopting a "God's eye" view, which is culturally associated with science (an objective overall view from above, of what is true) (Lemke, 2002) while in the press the images are deployed in a way that prompts the viewer to consider himself/herself as equal, more or less, to images' projected meaning. The message conveyed by this kind of visual syntax is that students, by studying the science subjects in school, can gain access to the

Table 7
The Imposition Relationships between the Content of the Images and the Viewers in the Science Textbooks of the Primary and the Lower Secondary School.

Imposition relationships	Frequency (percentage) Primary school	Frequency (percentage) Lower secondary school
Viewer's imposition	870 (62.7%)	754 (67.5%)
Equality	428 (30.8%)	293 (26.3%)
Imposition of what is represented	90 (6.5%)	70 (6.2%)
Total	1388*	1117*

*These totals correspond to the realistic representations only.

world of science and technology from a powerful social position. The corresponding message in the press is that science and technology are anthropocentric and human-serving endeavors. Also, no considerable variation was found between the imposition relationships established by the visual mode of the science textbooks of primary and lower secondary school texts (Table 7).

The degree of the viewers' involvement implied by the visual images

When considering the degree of viewers' involvement with the content of the visual images, it was found that the images in the school science textbooks and the press articles signify a high level of viewers' intimacy and familiarity with the meanings projected by the techno-scientific imagery. Specifically, 61.1% of the illustrations in the textbooks and 70.2% in the press represent the techno-scientific world as familiar to the viewer or at least as a world with which the viewer can be engaged (Table 8). Only a small percentage of the illustrations (13.2% in the textbooks and 8.6% in the press) present the techno-scientific world as alienating and beyond the viewers' reach.

Additionally, comparing the degree of the viewer's involvement promoted by the visual images of the science textbooks of the primary and the lower secondary level respectively, it was found that the science textbooks of both levels prompt the viewers to engage equally with what is represented (Table 9).

The results concerning the imposition relationships and the degree of the viewer's involvement show that the visual part of both kinds of non-specialised techno-scientific texts (science textbooks and press) promotes a kind of social-pedagogic relationship characterised by weak framing. 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 8
The Degree of the Viewers' Virtual Involvement with the Represented Agents in the School Science Textbooks and the Press.

Degree of involvement	Frequency (percentage) in textbooks	Frequency (percentage) in press
High	1533 (61.2%)	997 (70.2%)
Moderate	641 (25.6%)	300 (21.1%)
Low	331 (13.2%)	123 (8.6%)
Total	2505*	1420*

*These totals correspond to the realistic representations only.

Table 9
The Degree of the Viewers' Virtual Involvement with the Represented Agents in the Science Textbooks of the Primary and the Secondary School Respectively.

Degree of involvement	Frequency (percentage) Primary school	Frequency (percentage) Lower secondary school
High	830 (59.8%)	696 (62.3%)
Moderate	340 (24.5%)	296 (26.5%)
Low	218 (15.7%)	125 (11.2%)
Total	1388*	1117*

*These totals correspond to the realistic representations only.

Additionally, combining the results shown in Tables 6 and 8 above, it follows that the visual images of school science textbooks seem to empower the viewer much more than those in the press. As a result, school science textbooks tend to establish social-pedagogic relationships with their readers that are characterised by weaker framing compared to the framing established by the press. In other words, school science textbooks tend to pass over to their readers a higher proportion of the control over the communicative process. This trend though is relatively moderated since as shown in Table 8, the press visual images promote a higher level of the readers' involvement.

Table 10
Formality of the Visual Code of the School Science Textbooks and the Techno-scientific Articles of the Press.

Formality of visual representations	Frequency (percentage) in textbooks	Frequency (percentage) in press
High	311 (11.3%)	73 (4.5%)
Moderate	943 (33.4%)	824 (50.5%)
Low	1565 (55.5%)	733 (45.0%)
Total	2819	1630

The Formality of the Visual Code

It was found that only a small minority of the visual images in both school science textbooks and the press are of high formality (11.3% in the textbooks and 4.5% in the press) (Table 10). This means that both textbooks and press present the world through the visual code in a highly naturalistic, articulated and contextualised way. Contrary to the way experts use the visual code in order to describe reality in terms of abstractions and deeper regularities (Amann & Knorr Cetina, 1990; Lynch, 1990; Miller, 1998), the visual code of the school science textbooks and the press do not probe beyond the physical appearances of things but remains bound to their real-life likeness.

It must be noted though that visual images of high formality are more frequent in school science textbooks compared to press articles. This result is congruent with the corresponding result concerning the classification promoted by the visual images in the two types of texts and reinforces our conclusion that school science textbooks tend to present the techno-scientific knowledge as more specialised and distinct from the every-day knowledge in comparison to press articles.

Additionally, the images in the science textbooks of the lower secondary school are characterised by higher formality than the corresponding textbooks of the primary school, something that is also consistent with our finding concerning the classification projected by the visual part of the texts of these two educational levels and implying that as the educational level rises the students are gradually introduced to the more specialised content and codes of the techno-scientific knowledge domain (Table 11).

Table 11
Formality of the Visual Code of the Primary and Lower Secondary School Science Textbooks.

Formality of visual representations	Frequency (percentage) Primary school	Frequency (percentage) Lower secondary school
High	95 (6.4%)	216 (16.2%)
Moderate	489 (32.9%)	454 (34.1%)
Low	903 (60.7%)	662 (49.7%)
Total	1487	1332

Discussion

School science textbooks tend to rely on the visual imagery more than the press. This result suggests that school science textbooks are much more adaptive, in comparison to the press, to the general cultural climate that creates an imperative for higher levels of visualisation rather than written text (Kress, Jewitt, & Tsatsarelis, 2000). Furthermore, this finding comes in sharp opposition to the widely held belief that mass media use the potential of the visual mode much more extensively than school texts.

According to our results, visual images are characterised by weak classification, which means that they tend to portray techno-science as being close to every-day knowledge. Epistemologically, every-day knowledge is usually localised, bound to specific contexts and grounded on sensory perceptions (Irwin & Wynne, 1996; Layton, Jenkins, Macgill, & Davey, 1993). These features are visually realised by the prominence of realistic and analytical images in both school science texts and press articles. The trend of employing the visual mode in quite different ways than the experts do is further reinforced by the low formality of the pictorial representations in both types of text material. The infrequent use of illustrations characterised by high classification and formality in science textbooks has been also reported in other studies (Roth, Bowen, & McGinn, 1999) and might be a reason for the widely observed difficulties faced by students in producing and interpreting graphs (Leinhardt, Zaslavsky, & Stein, 1990).

A major implication of these findings is that both school science textbooks and press articles do not expose their non-expert readers to the corresponding world of the techno-scientific graphical conventions, rather they mainly relate the content of science with the salient features of physical reality. These conventions though form the basis for an acculturation in science, in the sense that their acquisition allows the participation (from more peripheral to central ways) in one of the important practices of the techno-scientific culture, which is the use of a specialised visual language

(Roth & Laweless, 2002). By not being exposed to the conventions of the techno-scientific images the lay readers then may be excluded from seeing and processing reality in a similar way with the experts (Lynch, 1985; Trumbo, 1999).

With reference to the social-pedagogical relationships projected by the visual images, it was found that in both kinds of texts these tend to form a social type of viewer who has considerable control over the intended meaning. More particularly, the text images seem to address a type of reader who has either imposition over the reading of the images (as is the case in the school science textbooks) or at least shares equal power with their content (as is the case in the press articles). This kind of viewers' pedagogic positioning is further reinforced by the finding that the visual images of these texts prompt the lay readers to become highly involved in their viewing.

Despite the overall picture described above, the comparison of the images in the school textbooks and the press material revealed some variations in the way that their visual images function. More particularly, it was found that the visual images of school science textbooks tend to strengthen the classification of the techno-scientific knowledge in comparison to press articles, hence forcing their readers (students) towards more specialised forms of techno-scientific knowledge. Additionally, school science textbooks seem to expose their readers to more stylised and abstract forms of visual images hence leading them to become more familiar with the usual techno-scientific practice of probing deeper than the surface characteristics of the various entities.

These variations in the 'scientificness' (in terms of both content and code specialisation) of the visual mode in the two types of texts, reflects the differences in their main objectives for communicating science and technology to non-experts. Specifically, the main objective of school science textbooks is to progressively introduce novice students to the highly specialised body of techno-scientific knowledge and the corresponding conventionalised ways of expression, while the primary objective of the press is to bring science and technology as close as possible to the every-day common-sense experiences of its lay readers.

In relation to the social-pedagogical relationships implied by the visual images in the two types of text, it was found that the school science textbooks use these images to empower the readers more so than the press. The underlying message of the visual part of the school science textbooks is that as the classification and the familiarity with the specialised techno-scientific codes becomes stronger, the student is prompted to acquire a sense of power over the communication process.

Comparing the visual representations of primary and lower secondary science textbooks, with respect to classification and the formality projected by their visual images, we found that the latter present techno-scientific knowledge as more specialised and remote from every-day experience by containing more conventional and high formality images. This trend towards more academic and abstract knowledge as the educational level rises, is further reinforced by the finding that the science textbooks of the lower secondary school use almost one third of the illustrations used in the corresponding primary textbooks, signifying a shift towards more abstract and of higher order thinking and learning, which according to our cultural tradition of

literacy, can be served better through the strict syntax of the written language rather than the rather ambiguous syntax of the visual images.

Furthermore, with regard to the social-pedagogical relationships that tend to be established by the visual images within the framework of pedagogic practice, we can conclude that the science textbooks of both the primary and the lower secondary levels tend to position their readers in a strikingly similar way allowing them to have imposition over a quite familiar world which visually calls them for involvement and participation.

These last two results (increased content and code specialisation and maintenance of a high degree of empowerment and involvement as one moves from the primary to the lower secondary educational level) reveal a trend where the more experienced and specialised a student becomes (move towards stronger classification and formality), the more he/she maintains his/her own control over the pedagogical process (maintenance of weak framing). This discursive trend of the visual mode contrasts strongly with the usual pedagogical practice of more teacher-centered approaches as school subjects become more academic and content-specialized.

Finally, we should note that apart from the specific findings discussed here we consider that the grid of our analysis as well as the operationalisation of its variables have some importance because they make possible the analysis of the pedagogical vis-à-vis the semiotical dimensions of the images included in techno-scientific texts. Our belief assumes that every text constructs meanings and the communication of these meanings interrelates not only pedagogical but also semiotical dimensions of equal importance.

Teaching Implications

It has widely been argued that the exposure of students to material coming from a variety of sources can enhance the degree of relevance and promote the goal of techno-scientific literacy for all (Bybee, 1997; De Vos & Reiding, 1999; Lijnse, Eijkelhof, Klaasen, & Scholte, 1990; Phillips & Norris, 1999). This argument is strongly supported from the findings reported here: this is because the pictorial representations employed in school science textbooks make restricted use of the extensive range of the semiotic-pedagogical opportunities of the visual mode by being mainly realistic (89%), analytical (61.8%) and of low/moderate formality (88.9%) and by projecting an image of a student that has power (65.5%) and is highly involved (61.2%) with their reading. It follows that, in order to enrich the meaning-making potential of the visual material employed in science classes without though departing from the accepted pedagogical trends at each educational level, we should add relevant material coming from other sources such as the press.

The above analysis of the differences of the visual images in the two types of text material examined here (school science textbooks of the primary and lower secondary school and press material) can lead to the development of teaching strategies for the effective incorporation of visual material from the press in science teaching

both at primary and lower secondary school. More particularly, in order for press material to be used effectively in science classes, specific pedagogic actions, as the ones suggested below would have to be adopted, so as to make the pedagogic functions of the images in press articles compatible with the corresponding functions of the images in the textbooks used at each educational level.

It can therefore be concluded that press material can be easily used in science teaching at the primary level since the degree of the content-specialisation (classification) and the formality of press material seems to be quite compatible with the corresponding classification and formality of the science textbooks of the primary school, both being very low. The only precaution that science educators teaching in primary schools should take when using press material, is to enrich it with additional iconographic material since the press tends to use far fewer visual images than primary science textbooks.

The situation though is more problematic when considering using press material in lower secondary science teaching. In particular, since the content-specialisation and the visual code elaboration of the press material is lower than the corresponding features of the science textbooks at this level, science teachers must ensure that the scientific perspective has been made very explicit prior the introduction of such material in their classes. The visual material from the press in this case could be used to provide a contrast with the scientific view.

Furthermore, the use of images from the press, which are characterised by low content-specialisation and low formality, can help students if they are appropriately guided to be not mislead by the salience of their realistic features, to interpret the more abstract and conventional images and to integrate them to give a global interpretation of the document (Pinto & Ametller, 2002). At this point special care should be taken in order to avoid providing science students with images from the press which have a pre-eminent metaphorical intention since the variety of meanings assigned to some elements of these images has been a source of difficulties for some students, leading them to end up with new connotations which are completely irrelevant to those of the designer of the images (Amettler & Pinto, 2002; Colin, Chauvet, & Viennot, 2002).

Finally, in relation to the social-pedagogic positioning of the students through the visual mode, it must be noted that at both levels (primary and lower secondary) press material should be used in a way that lowers the framing hence allowing students to exert their own control over the pedagogical process since the trend for weakening of framing is a dominant characteristic of the science textbooks at both primary and lower secondary levels. Science educators can use visual material from the press and simultaneously lower the framing in their classes by: a) providing their students with a broad collection of articles allowing them to select the appropriate ones for conducting various science based learning activities (e.g., project-work, essay-writing, authentic problem-solving) and b) selecting articles to be discussed in their classes characterised by visual images that tend to create a sense of empowerment and involvement for the students.

Our position is that the socio-pedagogical implications of the ‘language’ of the visual images employed in school are identifiable and amenable to specification. It

therefore seems that elements of this language could be made more generally accessible to science teachers through teacher preparation and professional development activities so as to overcome their widely held belief that visual images are trivially understandable and with only a complementary role in the conceptual development of students (Pinto & Ametller, 2002). Functional knowledge about the visual language would enable science teachers' control of the distinctive characteristics of this special kind of language and guide their students to exploit it more effectively.

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