SCIENCE CENTRES AS SITES FOR LEARNING: THE CASE OF A GREEK ENVIRONMENTAL CENTRE

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Abstract: *Given the lack of exploratory orientation of science education in most of the Mediterranean countries, Science Centres could enrich our efforts to teach the investigative nature of science more effectively. This study aims at presenting a grid for analyzing the pedagogical implications of the exhibits' design in a science centre. The construction of the grid is based on the theoretical notions of classification, formality and framing. The representational modes employed in a science centre (e.g. written language, formatting and layout of written text, two- and three-dimensional representations, lighting, etc) contribute to the modulation of the levels of classification, formality and framing. In order to illustrate the potential of the grid, we used it to analyze some of the exhibits of the 'Gaia' Environmental Centre in Greece. The results demonstrated that science is presented as a specialized body of knowledge (strong classification), in this case, expressed in vernacular and realistic codes (low formality) and consisting of elements that can be discovered through active personal involvement (weak framing). These results show that the design of a science centres' exhibits can potentially allow students to have access to the cognitive landscape of the specialized scientific knowledge by removing the barriers of the specialized expressive codes and by treating them as active explorers.*

Introduction

Science centres have been recently recognized as sites where the investigative and experimental nature of science can be effectively encountered by students (Falk and Dierking, 1992; Beiers and McRobbie, 1992; Crane, Nicholson, Chen and Bitgood, 1994; Henriksen and Jorde, 2001). 'Science centres' are institutions that are clearly distinguished from the more traditional 'science museums' in the sense that they demonstrate a shift in focus from the classical exhibition of objects of cultural heritage for ocular observation (as is the case in most of science museums) to the open-ended manipulation of exhibits. Hence, science centres typically aim to enable visitors to engage with processes and build an understanding for the fundamental concepts of science, thus bringing the notion of the scientific exploration into the exhibition hall (Oppenheimer, 1968; Gregory, 1989; McManus, 1992). We use the term 'science centres' to label collections of *interactive* exhibits in 'which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input' (McLean, 1993).

Given the lack of experimental and exploratory orientation of science education in most of the Mediterranean countries in comparison to the North European countries (Solomon and Gago, 1994), science centres could enrich our efforts to teach the nature of science more effectively.

Additionally, although science centres are well established in the Northern European region, they have only recently started to spread around the Mediterranean basin (Table 1).

TABLE 1: *Number of science centres in the Mediterranean region. Only 5 members of the European Collaborative for Science, Industry, and Technology Exhibitions Network (ECSITE) are included.*

Country	No of Science Centres
Italy	24
Spain	20
Portugal	7
Greece	2
Tunisia	1
Turkey	1

Source: ECSITE website: http://ecsite.ballou.be/net/beta.asp

Table 1 only includes the larger science centres in terms of the area covered by their exhibits and the number of visitors they attract and excludes many small regional centres that have not joined ECSITE.

Despite the currently restricted diffusion of the 'science centres' concept in the Mediterranean countries, such institutions are spreading at a very vigorous rate, in terms of both the number of visitors they attract (the vast majority of whom are usually school students) and their contribution to raising the level of public awareness about techno-scientific issues. For example, in Greece, two of the most prominent science centres (Technical Museum of Thessaloniki and The Environmental Education Centre Gaia) between them attract around 180.000 visitors per year, of whom around 70-90% are school students.

Thus, the combination of the dynamic spreading of science centres together with the potential usefulness of these institutions in promoting the investigative and experimental nature of the corresponding school subjects leads to the need for further research about the pedagogical presuppositions and the implications on their use as teaching resources.

During the last two decades, a considerable amount of research has been conducted on the issue of science centres. This body of research can be organised into three prevailing strands. The first strand focuses on the cognitive (Falk and Dierking, 1992; Beiers and McRobbie, 1992; Crane, Nicholson, Chen and Bitgood, 1994) and affective impact (Dierking and Falk, 1994; Tuckey, 1992; Wellington, 1989) of the science centres on students. The second strand concerns the analysis of the exhibits' design (Alt and Shaw, 1984; Borun, Massey and Lutter, 1993; Perry, 1993; Screven, 1990). Finally, the third strand brings highlights the relationship between the design characteristics of the exhibits and the learning outcomes (both cognitive and attitudinal ones) (Boisvert and Slez, 1995; Seagram, Patten and Lockett, 1993).

This study is situated in the second strand and aims to analyze the pedagogical implications of the exhibits' design in a science centre. This kind of analysis is very important for a science centre since the style of the exhibits' presentation deeply affects the kinds of thinking engaged in by visitors (McManus, 1989). The term design refers to 'the uses of semiotic resources, in all semiotic modes and combinations of semiotic modes' (Kress and van Leeuewen, 2001). In this sense, a science centre is treated as a 'text' in which a multiplicity of representational modes interweave in order to facilitate a specific type of techno-scientific discourse.

In order to analyze a science centres' exhibits in terms of their pedagogical implications, we use the theoretical notions of *classification* (Bernstein, 1996), *formality* (Halliday, 1996) and *framing* (Bernstein, 1996).

More particularly, 'classification' determines the epistemological relationship between knowledge categories (Bernstein, 1996). In particular, the categories we examine are the specialized 'techno-scientific knowledge' and the 'everyday knowledge'. The exhibits promote strong classification when they portray techno-scientific knowledge as epistemologically distinct from the everyday knowledge. On the contrary, they promote weak classification when they present these two types of knowledge as blurred.

'Formality' corresponds to the degree of abstraction, elaboration and specialization of the expressive codes employed. Low formality corresponds to codes resembling the vernacular ways of expression or approaching the realistic appearance of things. High formality corresponds to specialized codes that define reality in terms of abstractions and deeper regularities (Halliday, 1996; Kress and van Leeuwen, 1996). The notions of classification and formality are used to describe the access allowed by the exhibits into the specialized techno-scientific knowledge.

Finally, 'framing' refers to the locus of control over the communication established by the exhibits (Bernstein, 1996). In other words, framing regulates the socio pedagogic relations within the context of a science centre. Strong framing implies that the visitor is deprived of any control over the ways he/she will interact with the exhibits; weak framing implies that the visitor is offered a wide range of options for accessing the science exhibit. The notion of framing can be conceptually further elaborated by referring to the dimensions of: a) the power (hierarchical) relationships implied between the exhibits and the visitor, b) the control of the conditions for the visitors' involvement with each individual exhibit and c) the control of the conditions under which visitors' access the various parts of a science centre (degree of linearity of a science centre). Therefore, strong framing means that the exhibits socially disempower visitors, their design discourages involvement and, also, that the science centre as a 'text' does not allow multiple paths for its 'reading'. On the contrary, weak framing means that the exhibits' design creates a feeling of social equity or even places the visitors in a position of superiority, encourages involvement and allows for multiple routes of access.

The above definitions of the notions of classification, formality and framing, show that when considered in combination they correspond to the broader issue of students' access to the pedagogic process. This kind of access is related to the students' potential to share either the specialized content delivered (classification) or the specialized codes employed (formality) as well as to participate in the determination of the rules that organize learning as a social process.

All representational modes employed in a science centre contribute (perhaps not with equal weighting) to the modulation of the levels of classification, formality and framing and hence together determine its pedagogical implications. The representational modes examined here are written language, formatting and layout of written text, two-dimensional and three-dimensional still representations and lighting. Of course more representational modes such as sound or moving images could also be found in the context of a science centre. In this paper, we decided to restrict our analysis to these four representational modes, even though we are fully aware of the need to extend our analysis in the future.

In the next section, we will present the way the notions of classification, formality and framing become operational for each of the aforementioned modes.

The analysis grid

Written language

Classification

In the written texts of a science centre, the measure of classification is taken to be the density of the pieces of specialized techno-scientific factual information (number of pieces of information/total number of words) in each text. By the term ‘pieces of specialized techno-scientific factual information’ we mean definitions, explanations, qualitative and quantitative statements; e.g. the statement ‘Alpha Centauri is four light years away from Earth’ counts as one piece of techno-scientific information. High density implies strong classification whereas low density implies weak classification.

In Table 2, we present the way written language modulates the level of classification promoted by the exhibits of a science centre.

TABLE 2: *Modulation of classification by written language*

Marker of classification	Strong classification	Weak classification
Techno-scientific factual informational density (no of factual pieces of information per no of words in the text)	High density	Low density

Formality

Science uses a specialized linguistic code. The basic realizations of the specialized character of the techno-scientific linguistic code (formality) are the following: a) specialized terminology and notation, b) nominalizations, c) syntactic complexity and d) the use of passive voice (Halliday and Martin, 1996). These features will be treated as indicators of the level of formality of the written language of text as shown in Table 3.

Framing

The interpersonal/affective functions of written language are realized by specific grammatological features. In particular, the power (hierarchical) relationships are linguistically realized by the type of sentences used. A sentence can be: (a) imperative, (b) interrogative, or (c) declarative. The imperatives denote

TABLE 3: Modulation of formality by written language

Formality markers	**High Formality**	**Low Formality**
Terminology	Presence of specialized notation and terminology	Absence of specialized notation and terminology
Nominalizations	Prevalence of nominal groups consisting of more than two nouns	Prevalence of single nouns
Syntactic complexity	Prevalence of hypo-taxis (subordination)	Prevalence of parataxis (coordination)
Use of passive voice	Prevalence of verbs in passive voice	Prevalence of verbs in active voice

a clear authority of the 'implied author' and hence, in this case, the framing is strong. The interrogatives denote that the 'implied author' still exerts control over the communicative process by selecting what will be asked, however, in this case, the control is moderated by the fact that the reader can have options in answering a question that can take multiple appropriate answers. Hence, the interrogatives can also be considered as signifying strong framing. Finally, in the declaratives the authority of the 'implied author' might still be present but is not as obvious and so the framing is weak.

Furthermore, the degree of the readers' involvement established by a text, is linguistically realized by the person of the verbs in it. In specific:

(a) The *first singular person* (I) represents exclusively the 'implied author'. This person is rarely met in the techno-scientific texts.
(b) The *second singular person* (You) represents the visitor. This person makes the rules of communication explicit and hence it tends to define clearly the conditions of the visitors' participation in the communication process and therefore the framing is strong.
(c) The *first plural person* (We) represents various situations. The 'We' can be regarded as meaning 'Me and You' but also as meaning 'Myself and others but not you'. Therefore, this person defines the conditions of the visitor's participation in an ambiquous way. Framing is again considered as strong.
(d) The *second plural person* (You) represents the visitor again who in this case is addressed as if he/she belongs to a broader social group and framing is considered as strong.
(e) The *third singular or plural person* (He/She/It, They) signifies that what matters is the content of the text and not the communicating agents. Therefore, framing is weak.

In Table 4, we summarize the way the various linguistic indicators modulate the level of framing.

TABLE 4: Modulation of framing by written language

Framing markers	Strong Framing	Weak Framing
Type of sentence	Imperatives, Interrogatives	Declaratives
Person of the verbs	Prevalence of the second singular, first plural and second plural persons	Prevalence of third singular or plural person.

Formatting and layout of the written text

The formality of a written text is based on both the formality of its language (Halliday, 1996) and its formatting and layout (Kress and van Leeuwen, 2001). We will focus on the text properties that contribute to the formality of a written text at the level of its material appearance. These properties refer to the individual writing characters, the lines of text or to the appearance of the text as a whole (see Table 5).

The formality of a text increases the more uniform its writing characters and lines are and the less it deviates from a typical appearance, at least, as this has been culturally consolidated in the western literate tradition (e.g. characters of uniform colour, horizontal lines with uniform spacing, text with orthogonal shape, etc). In Table 5, we present the way the individual elements contribute to the formatting and layout of a text and so can modulate its overall formality.

TABLE 5: Modulation of a texts' formality by the elements that determine its formatting and layout

Texts' properties	High Formality	Low Formality
Individual writing characters: Size, Colour, Inclination, Font	- Uniformity across the whole text	- Non uniformity across the whole text
Lines of the text: Size, Colour, Inclination, Shape, Spacing	- Horizontal lines - Uniformity with regard to the rest of the properties	- Non horizontal lines - Non uniformity with regard to the rest of the properties
Text as a whole: Shape, Inclination	- Orthogonal shape - Horizontal inclination	- Non orthogonal shape - Non horizontal inclination

Two-dimensional and three-dimensional representations

(a) Classification (content specialization)

The two-dimensional and the three dimensional representations contribute to the level of classification and hence to the degree of the content specialization of the scientific knowledge projected by a science centre. Specifically the content specialization promoted by the two and three-dimensional representations is determined by:

a) The kind of represented agents
b) The form, and
c) The function of each representation.

As the ontological distance between the represented entities and the entities of the everyday world increases so does the level of classification (e.g. a model of an atom has a large ontological distance with the entities of the everyday world and hence contributes to increased classification). Furthermore, as far as their form is concerned, the representations are distinguished into *conventional*, *hybrids* and *realistic* ones (Koulaidis, Dimopoulos, Sklaveniti and Christidou, 2002). All representations that represent reality in a codified way are considered as conventional. These representations are constructed according to the techno-scientific conventions and are usually graphs, maps, flow-charts, molecular structures and diagrams. Hybrids are usually conventional representations with added realistic features. Finally, all representations that exhibit reality according to visual perception are considered as realistic.

In relation to their function, the representations are divided into classificational, analytical, narrative and metaphorical (Kress and Van Leeuwen, 1996). Classificational representations are those that exhibit the type of relationships between the represented entities or, in other words, a taxonomy. Narrative representations are those that represent 'unfolding actions and events, processes of change and transitory spatial arrangements' (Kress and Van Leeuwen, 1996, p.56). In this kind of representations, the represented action is visualized by a vector, either shown explicitly or implied. Analytical representations are those that focus on the relations between the 'objects' of representation in terms of a part-whole structure. The parts of the whole may be labeled or it may be left up to the viewer to do this. Finally, metaphorical representations are those that 'connote or symbolise meanings and values over and above what they literally represent' (Kress and Van Leeuwen, 1996, p.45). The represented participants in these images are conventionally associated with specific cultural symbols.

In Table 6, we present the way that all these elements of the two and three-dimensional representations modulate the level of classification.

TABLE 6: Classification modulation by two and three-dimensional representations

Representational characteristics	**Strong classification**	**Weak classification**
Represented entities	Entities characterized by large ontological distance from the entities of the everyday world.	Entities characterized by small ontological distance from the entities of the everyday world.
Form	Conventional representation or hybrid	Realistic representation
Function	Classificational, Analytical, Narrative	Metaphorical

(b) Formality (codes' specialization)

The two and three-dimensional representations contribute also to the level of the exhibits' abstraction and hence to the level of their formality. The more an image represents the deeper 'essence' of what it depicts by downgrading the superficial variability of the external features, the higher is its formality. This is accomplished by reduced articulation. Hence, low formality, corresponds to representations very close to realism while high formality corresponds to techno-scientific realism that defines reality in terms of what things are like generically or regularly (Kress and van Leeuwen, 1996).

The formality of the representations can be estimated using relevant indicators. These indicators record particular constitutive elements of the representations that contribute to their level of abstraction (degree of articulation). The markers used to evaluate the formality of the two-dimensional representations are: the presence of *elements of the techno-scientific code* (geometrical shapes, vectors, etc), *colour differentiation*, *colour modulation*, and the *degree of articulation of their background*.

The corresponding indicators for evaluating the formality of the three-dimensional representations are all those used for the two dimensional ones except the degree of articulation of their background, plus the *part of the three-dimensional objects represented* and their *texture*.

For example, a three-dimensional representation of a globe, whose surface appears in relief, without built-in elements of the techno-scientific code and characterized by the use of multiplicity of colours and colour shades (e.g. deep blue for the points of large oceanic depth) can be considered as a three-dimensional representation of low formality. On the contrary, a globe appearing in half (as if it was shown from the moon), monochromatic, with a flat surface and with elements of the techno-scientific code added on (e.g. arrows representing the oceanic draughts) is characterized by high formality.

TABLE 7: Modulation of formality by two and three-dimensional representations

Representational characteristics	**High Formality**	**Low Formality**
Elements of the techno-scientific code	Existent	Non-existent
Colour differentation	One or two colours	Three or more colours
Colour modulation	No shades	More than one shades
Contextualization1	Monochromatic background or absence on any background	Background with more than one colours
Part of the object represented[2]	Partial representation	Full representation
Texture[2]	Flat surface	Relief surface

1. Only for two-dimensional representations.
2. Only for three-dimensional representations.

(c) Framing

Finally, the two and three-dimensional representations tend to contribute to the regulation of the interpersonal/affective relationships between the exhibits and the visitors. Specifically, the element of the two-dimensional representations that contributes to the formulation of the power (hierarchical) relationships between the exhibits and the visitors is the *vertical angle of shot*. An image shown from a low angle depicts a relationship in which the content of the image has power over the viewer and hence the framing is strong. If an image is shown either at eye-level or from a high angle, this depicts a relationship in which the image has equal or less power in relation to the viewer and hence the framing is weak. For the case of the three-dimensional representations the corresponding characteristics are the *exhibits' size* and the *vertical angle of view*.

Furthermore, the degree of a visitor's involvement with what is represented in the images as a measure of his/her potential to participate in the communication process is visually realized by the *distance* and *the horizontal angle of shot*. In particular, the distance of shot regulates the level of intimacy that is possible to be established between what is represented and the visitor and takes the values of close, medium and distant shot, which correspond to an intimate/personal, social and impersonal relationship respectively.

The horizontal angle of shot signifies the degree of involvement that the visitor can have with the represented agents and takes the values of frontal and oblique angle. 'The difference between the frontal and the oblique angle is the difference between familiarity and detachment' (Kress and Van Leeuwen, 1996, p.143). The corresponding characteristics for the case of the three-dimensional representations are the *minimum distance* that a visitor can *approach* each representation and the *horizontal angle of view*[1].

For example, a three-dimensional representation of a celestial body that is large in size, can be viewed from a high and oblique angle and which cannot be touched, tends to create a feeling of diminishment and alienation and hence promotes strong framing. On the contrary, a three-dimensional representation of a molecular model, which can be viewed at the eye-level and frontally and which can also be manipulated by a visitor tends to create a feeling of familiarity, calls for involvement and hence promotes weak framing.

In Table 8, all the individual characteristics that modulate the level of framing for the two and three-dimensional representations are shown.

TABLE 8: Modulation of framing by two and three-dimensional representations

Representational characteristics (Power relationships)	**Strong framing**	**Weak framing**
Vertical angle of shot[1]	Low angle	Eye-level or high angle
Vertical angle of view[2]	Viewed from below	Viewed at eye-level or from above
Size[2]	Large	Human like size or less
Representational characteristics (Visitors' involvement)	**Strong framing**	**Weak framing**
Horizontal angle of shot[1]	Oblique	Frontal
Horizontal angle of view[2]	Side view	Frontal view
Minimum distance of approach[2]	The visitor can only see but not manipulate the exhibit	The visitor can manipulate the exhibit

1. Only for two-dimensional representations.
2. Only for the three-dimensional representations.

Lighting

Lighting in a science centre can modulate both the level of abstraction of the exhibits, and hence the level of the exhibits' formality, and the range of options available to the visitors, and hence the level of framing.

(a) Formality

Abstraction is again accomplished by reduced articulation. Thus, the more elements of lighting contribute to the realistic appearance of the exhibits, the lower the formality. These elements are: the *realism of the colours* of lighting, the *colour differentiation* as well as the *degree of directionality* of lighting.

The more realistic and differentiated the colours of lighting are and the more diffuse the light that falls on the exhibits is the lower the formality. On the contrary, a well known technique often employed in science fiction films is the use of unrealistic and usually monochromatic lighting which takes the form of very narrowly focused light beams. This technique creates a futuristic and technocratic atmosphere signifies high levels of formality. An example of this technique is the intense blue lighting emitted in the form of narrow light beams in the descent of the aliens' spacecraft in Spielberg's film *Close Encounters of the Third Type*.

In Table 9, we present all the lighting properties that modulate the level of the exhibits' formality.

TABLE 9: Modulation of formality by lighting

Representational characteristics	**High Formality**	**Low Formality**
Degree of colours realism	Unrealistic colours	Realistic colours
Colour differentation	One or two colours	Three or more colours
Degree of directionality	Focused light beams	Diffuse lighting

(b) Framing

Lighting can also modulate the level of framing projected by a science centre. The lighting property that plays a crucial role in determining the level of framing is the intensity of illumination of an exhibit in relation to the corresponding intensity of the surrounding exhibits. In particular, when the illumination of an exhibit is more intense in comparison to the illumination of its surroundings then it becomes more prominent and so in an implicit way the visitor is forced to draw his/her attention to it. In this way, lighting reduces the visitor's control and hence leads to strong framing. On the contrary, when an exhibit is not more intensely illuminated with respect to its surroundings, there is no implied hint to the visitor to draw his/her attention to it and hence the framing is weak.

In Table 10 below, we present the way lighting can modulate the level of framing.

TABLE 10: Modulation of framing by lighting

Lighting property	Strong framing	Weak framing
Intensity of lighting with respect to the surroundings	More intense lighting with respect to the surroundings	Uniform lighting everywhere

Degree of linearity of the science centre

The presentation of all the exhibits in a science centre as a whole constitutes a separate representational system carrying its own semiotic meaning. The prevailing feature of this composition that will be examined here is the degree of its linearity.

The degree of linearity reveals the strength of each exhibit's connections to the other exhibits. This strength can be estimated by the existence of signs of explicit or implicit (e.g. morphological features such as common colour, background or lighting) reference to other exhibits, the proximity between the exhibits, as well as the presence of connective elements, such as the numbering of different parts of an exhibit or of a group of exhibits. For a specific exhibit, a low linearity grade means that it can be accessed in a rather independent way without the need to refer to any other exhibit. A high linearity grade means that an exhibit is tightly linked to one or more other exhibits and so the visit must follow a prescribed path in his/her tour around the science centre. As a result, the more a science centre contains exhibits with a high linearity grade, the more the visitors have to comply with a specific path of navigation during their visit and the more the exhibition tends to be characterized as linear. In this case, the visitor has restricted control and hence framing is strong. On the contrary, the less linear a science centre is, the more a visitor is allowed to navigate through it in a multiplicity of ways and hence the promoted framing is weak.

In summary, we present in Table 11 the functions of all the representational systems analyzed here. All these systems cooperate so as to create a coherent discursive ensemble that tends to shape the pedagogical meaning of a science centre. The messages are either explicitly or implicitly communicated to a visitor through a process called synesthaisia, meaning that all his/her senses take part in their reception (Kress and van Leeuwen, 2001).

TABLE 11: Functions of all the representational systems employed in a science centre

Representational system	Classification	Formality	Framing
Written language	•	•	•
Text formatting and layout		•	
Two dimensional representations	•	•	•
Three dimentional representations	•	•	•
Lighting		•	•
Degree of linearity			•

The sample

The grid presented above was used to analyze one thematic units of the 'Gaia' science centre[2]. 'Gaia' is an Environmental Research and Educational Centre, co-funded by the EU Cohesion Fund and the Greek Ministry of the Environment. It operates since June 2001 in Kifissia, Athens, Greece and its main objectives are:

- to promote a new approach to environmental education, supported by the use of new technologies
- to promote research actions in a wide range of environmental issues, and
- to act as a documentation centre for publication on environmental topics.

The exhibition of 'Gaia' was designed with the collaboration of experts from the London Natural History Museum. It covers a surface area of about 2000 m^2 and it consists of three main parts. The first part is a presentation of the Earth' s natural systems (thematic units 1-6). The second part is a summary of human inventiveness in the use of the Earth's natural resources (thematic unit 7). In the third part, visitors are introduced to environment-friendly ways of serving human needs (thematic units 8-14).

The thematic unit examined here, belongs to the first part of the 'Gaia' exhibition and is titled 'Structure and Function of the Earth.' It consists of four groups of exhibits, which focus on the issue of solar radiation and the Earth's atmosphere. These groups are as follows:

a) ‘Sun, the Earth’s Feeder’: This group of exhibits focuses on the way the solar radiation interacts with the Earth’s atmosphere. The Sun and its radiation are represented via intense yellow lighting. There are also three accompanying texts and one three-dimensional model of solar radiation. This three-dimensional representation corresponds to a transparent tube in the shape of a sinusoidal curve with small light bulbs inside.
b) ‘Types of Solar Beams’: This group presents the spectroscopic analysis of solar radiation. Specifically, it consists of seven screens, each presenting one text concerning a different part of the solar spectrum (gamma rays, X-rays, ultraviolet rays, visible light, infrared radiation, microwaves and radio waves). The press of a button activates each screen independently.
c) ‘Earth and the Atmospheric Layers’: This group concentrates on the structure of the Earth’s atmosphere. It consists of a three-dimensional model of a quarter of the Earth from the edge of which start four concentric two-dimensional cycles each corresponding to one of the four layers of the Earth’s atmosphere. The group also contains an introductory text and one text for each of the four atmospheric layers.
d) ‘Atmosphere: the Earth’s Shelter’: This group shows the protective role of the atmosphere for the maintenance of life on the Earth’s surface. In particular, it contains a synthesis of three texts and two two-dimensional representations presenting the consequences of the use of aerosols for the atmosphere – such as the ozone hole.

In total eighteen texts, two two-dimensional and two three-dimensional representations were analysed. Additionally, the lighting of all four of the groups of exhibits as well as the degree of linearity of the thematic units were also analysed. In particular, these representational modes were analysed in terms of their contribution to the level of content specialization (classification), the codes’ elaboration (formality), and their interpersonal/affective function (framing). The results will allow us to draw some conclusions on the pedagogical functioning of science centres, particularly in respect to the issue of promoting an exploratory teaching of science.

Results

Classification

As is evident from Table 11, the representational modes that contribute to the content specialization (classification) of a science centre are the written language and the two and three-dimensional representations.

The written language of the texts examined, promotes high levels of classification and hence presents the content of techno-scientific knowledge as a specialized and quite distinct form, as compared to every-day, commonsense knowledge. We do not mean to imply that there is no reference to the every-day experiential world of the visitors but that this is mainly done by providing examples of the way the specialized techno-scientific knowledge is applied influencing our everyday lives. More particularly, 13 out of the 18 texts analyzed contain more than one piece of factual information per ten words. It must be noted though that given the fact that these texts are all very short (mean number of words per text=24.3, s.d=13.8), on average, Gaia's texts do not usually provide more than three pieces of factual information, hence, they do not require intense cognitive effort on the part of the visitors so as to grasp the presented techno-scientific content. A typical text usually consists of two parts. The first part presents the essential background pieces of techno-scientific factual knowledge and the second part describes the way this underpin lies behind a number of everyday applications. An example is the following:

> 'The light beams arrive at various wavelengths, which are widely recognized as colours. When all the wavelengths are seen together, light is perceived as white. When the white light is analyzed through the rain-drops, it forms the well-known rainbow. Plants need light to produce food, while animals need light to see.'

The trend for strong classification is further reinforced by the form and function of the two-dimensional and three dimensional representations. In particular, as far as their form is concerned, the two three-dimensional representations and the one two-dimensional representation are *hybrids,* whereas, with respect to their function, the two two-dimensional representations are *analytical* and the two three-dimensional representations are *narrative* ones.

Formality

The level of formality of a science centre's exhibits is determined by all the representational systems presented here except the degree of linearity. In particular, the written language of the eighteen texts is characterized by low formality in all of the cases. Additionally, the texts' formatting and layout contributes also to the low levels of formality (in 15 out of the 18 texts). On the contrary, the two and three-dimensional representations (in three out of four cases) are characterized by high levels of formality. Finally, low levels of formality characterize lighting in all cases.

All the previous results converge to a prevailing image according to which, Gaia's exhibits are characterized by low levels of formality. This means that most of the representational modes except of the two and three-dimensional representations present the content of the exhibits using codes close to the vernacular and realistic ways of expression.

Framing

As far as the social distribution of the control over the communicative process established in the context of the Gaia science centre, the results from all the representational modes lead to the conclusion that the visitors are allowed a great deal of autonomy in accessing the exhibits and hence are treated as socially equal partners who are highly motivated to engage with them.

More particularly, the linguistic code of all eighteen texts provokes a weak framing by making extensive use of declarative sentences and by using verbs in the third singular or plural person. In this way, the communicating agents seem to withdraw from the scene and greater emphasis is placed on the content to be communicated. The two two-dimensional and two three-dimensional representations also promote the same levels of framing, respectively. Finally, the weak framing is further reinforced by the low levels of linearity within each of the four groups of exhibits. In particular, in three of these four groups of exhibits the degree of internal linearity is low allowing the visitors to access each exhibit in a rather independent way and only in one of them the structure imposes on the visitors a linear way of access.

Discussion

The analysis of a small but representative part of a typical science centre along the dimensions of classification, formality and framing revealed the way the visitors are socially constructed as learning subjects within the framework of similar institutions. More particularly, it was found that the design of the exhibits in the Gaia Science Centre projects an image of science as a distinct form of knowledge (strong classification) in relation to the everyday commonsense knowledge. The scientific knowledge is also presented as the key required for explaining the functioning of everyday natural phenomena and of very familiar technological devices.

On the other hand, the specialized nature of the scientific knowledge does not prevent it from being expressed in codes of low formality. Such codes acting at a superficial level usually pose barriers in the understanding of the relevant subject matter and alienate most of the students from the effort to grasp the deeper meanings of the scientific concepts (Martin and Veel, 1998). Since the expressive codes of low formality are very close to the vernacular ways of communicating and to the realistic appearances of things, the attempt is to link the specialized knowledge with the everyday experiential world not only in terms of its potential to provide explanations but also in terms of the vernacular and realistic codes employed.

With regards to the social positioning of the visitors as learners in the context of the Gaia Science Centre, we found that the design of the exhibits addresses a visitor who is highly motivated to interact with the exhibits and is also extremely autonomous in deciding his/her own learning experiences (weak framing). This model of the learner is drastically different from the model formulated within formal educational settings where the students usually remain passive while being guided in a strict predetermined way towards the acquisition of a highly structured body of knowledge.

The generated sense of self-determination and control over the projected knowledge can definitely reveal to the students the investigative, playful and exploratory nature of science and hence contribute to the change of the widely held view among students that science is a set of finalized truths that should only be learned by rote for the purpose of passing exams (Driver et al., 1996). The undertaking of full control over the communication process on the part of the learner (weak levels of framing) and the high levels of autonomy in initiating, continuing or redirecting his/her own learning is possibly the most important characteristic of the pedagogical framework of a science centre that make the experience of visiting it so unique so as to generate strong affective outcomes (McManus, 1993; Roberts, 1993; Uzzell, 1993).

The increased probability that self-directed learning can occur in a science centre is further reinforced by the fact that such institutions, by being multimodal, can cater for different learning preferences. The personification of the learning experience due to the multimodality of a science centre is based on the theory of multiple intelligences (Gardner, 1993). According to this theory, a person can exhibit seven types of intelligences, which are the linguistic, the logico-mathematical, the spatial, the musical, the bodily kinaesthetic, the interpersonal and the intrapersonal intelligences.

The employment of diverse representational modes (e.g. written text, lighting, visual representations, etc) in science centres can help the students to make meaning of the conceptual framework of science activating a wider range of their intelligences than is usually possible through the use of more conventional teaching resources (e.g. textbooks).

In summary, we can say that the science centre regulates a specific image of science as a knowledge system and accordingly a certain type of visitors as science learners. More particularly, science is presented, in piece meal format, as a specialized body of knowledge (strong classification) which can provide the basis for the explanation of the everyday world, expressed in vernacular and realistic codes (low formality) and consisting of elements that can be discovered through active personal involvement and free exploration. The corresponding image of the science learner that emerges, is a person who each time needs to grasp few essentials of the techno-scientific content in order to be able to explain its natural and technological environment, without needing to be tangled up with the complexities of the specialized and abstract techno-scientific conventional expressive systems, but, on the other hand, definitely needing to develop an exploratory and independent approach towards science learning.

This emerging picture could prove extremely useful from a pedagogical point of view, since it combines the communicative features found in another study (Koulaidis, Dimopoulos, Sklaveniti, 2002) of conventional educational resources (e.g. textbooks) of both the primary (strong classification, low formality, strong framing) and the lower secondary level (strong classification, high formality and weak framing) as well as of popularized techno-scientific material (short texts requiring limited attention span, lively presentation through the use of multimodal resources and links with everyday applications). The combination of various, also features found in other communicative contexts (school and wider culture), makes the science centre a ‘text’ that is easily adaptive to other texts already encountered by the students.

Furthermore, the identification of the science centre’s special discursive characteristics in relation to the corresponding characteristics of other learning environments demonstrates the way that it could be used for pedagogical interventions, so as to change both the students’ perception of the nature of science and of themselves as learning subjects tied to action agendas that require little initiative.

In conclusion, we would like to note that the grid used for the analysis of the Gaia Science Centre, could also be used for analyzing other multimodal texts employed as teaching resources in science education (e.g. CDRoms, WWW sites, Video, etc). The analysis of all these educational resources along the common dimensions of classification, formality and framing could reveal underlying pedagogical principles that determine the construction of their techno-scientific messages and, hence, would allow the use of these resources within the formal educational system in a manner that is more theoretically informed, than is usually the case.

Notes

1. An exhibit can of course be both approached to varying minimum distances and viewed at different horizontal angles. In this particular case though, what is meant is whether the exhibits arrangement privilege any specific distance of approach (e.g. barrier in front of an exhibit, or exhibit in a glass case) or any specific angle of view (e.g. frontal view, side view).

2. The Gaia science centre consists of fourteen thematic units titled: 1. With Nature, 2. Our world today, 3. Earth's Uniqueness in the Universe, 4. Structure and Function of the Earth, 5/6. Natural Equilibrium, 7. Making use of the Earth, 8. Meeting the challenge, 9. The energy challenge, 10. The transportation challenge, 11. The natural resources challenge, 12. The water challenge, 13. Food challenge and 14.With Nature.

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References

Alt, M. B. and Shaw, K. M. (1984) 'Characteristics of ideal museum exhibits.' *British Journal of Psychology*, Vol. 75, 25-36.

Beiers, R.J. and McRobbie, C.J. (1992) 'Learning in interactive science centres.' *Research in science education*, Vol. 22, 38-44.

Bernstein, B. (1996) *Pedagogy, Symbolic Control and Identity: Theory, Research, Critique*. London: Taylor and Francis.

Boisvert, D.L. and Slez, B.J. (1995) 'The relationship between exhibit characteristics and learning associated behaviours in a science museum discovery space.' *Science Education*, Vol. 79, 503-18.

Borun, M.; Massey, C. and Lutter, T. (1993) 'Naïve knowledge and the design of science museum exhibits' *Curator*, Vol. 36, 201-19.

Crane, V.; Nicholson, H.; Chen, M. and Bitgood, S. (eds) (1994) *Informal Science Learning: What research says about television, science museums, and community-based projects*. Dedham, Mass.: Research Communication.

Dierking, L.D. and Falk, J.H. (1994) 'Family behaviour and learning in informal science settings: A review of research', *Science Education*, Vol. 78, 57-72.

Driver, R.; Leach, J.; Millar, R. and Scott, P. (1996) *Young Peoples' Images of Science*. Buckingham: Open University Press.

Falk, J.H. and Dierking, L.D. (1992) *The Museum Experience*. Washington, D.C.: Whalesback Books.

Gardner, H. (1993) *Frames of Mind: The Theory of Multiple Intelligences*. New York: Basic Books.

Gregory, R., (1989) 'Turning minds on to science by hands-on-exploration: The nature and potential of the hands-on medium.' In M.Quin (ed.) *Sharing Science: Issues in the Development of Interactive Science and Technology Centres*, pp. 1-9. London: Nuffield Foundation on behalf of the Committee on the Public Understanding of Science.

Halliday, M.A.K. (1996) 'On the Language of Physical Science.' In M.A.K. Halliday and J.R. Martin (eds) *Writing Science: Literacy and Discursive Power*, pp.54-68. London: The Falmer Press.

Henriksen, E. and Jorde, D., (2001) 'High School Students' Understanding of Radiation and the Environment: Can Museums Play a Role?' *Science Education*, Vol. 85, 189-206.

Koulaidis, V.; Dimopoulos, K. and Sklaveniti, S. (2002) 'Analysing the texts of science and technology : school science textbooks and daily press articles in the public domain.' In M. Kalantzis; G. Varnava-Skoura and B. Cope (eds) *Learning for the Future*, pp.209-240. Sydney: Common Ground.

Kress, G. and Van Leeuwen, T. (1996) *Reading Images: The Grammar of the Visual Design*. London and New York: Routledge.

Kress, G. and vanLeeuwen, T. (2001) *Multimodal Discourse: The Modes and Media of Contemporary Communication*. London: Arnold, p.5.

Martin, J.R. and Veel, R. (eds) (1998) *Reading Science: Critical and Functional Perspectives on Discourses of Science*. London: Routledge.

McLean, K. (1993) *Planning for People in Museum Exhibitions*. Washington: Association of Science-Technology Centres.

McManus, P.M. (1989) ‘What people say and how they think in a science museum.’ In D.Uzzell (ed.) *Heritage Interpretation: Vol.2. The visitor experience*, pp.156-65. London: Belhaven Press.
McManus, P.M. (1992) ‘Topics in museums and science education.’ *Studies in Science Education*, Vol. 20, 157-82.
McManus, P.M. (1993) ‘Thinking about the visitor’s thinking.’ In S. Bicknell and G. Farmelo (eds) *Museum Visitor Studies in the ’90s*, pp.108-13. London: Science Museum.
Oppenheimer, F. (1968) ‘A rationale for a science museum.’ *Curator*, Vol. 11: 208–211.
Perry, D.L. (1993) Beyond cognition and affect: The anatomy of a museum visit.’ *Visitor Studies: Theory, Research and Practice*, Vol. 6, 43-7.
Roberts, L.C. (1993) ‘Analysing (and intuiting) the affective domain.’ In S. Bicknell and G. Farmelo (eds) *Museum Visitor Studies in the ’90s*, pp.97-101. London: Science Museum.
Seagram, B.C., Patten, L.H. and Lockett, C.W. (1993) ‘Audience research and exhibit development: A framework.’ *Museum Management and Curatorship*, Vol. 12, 29-41.
Solomon, J. and Gago, J.M. (eds) (1994) *Science in School and the Future of Scientific Culture in Europe*. Euroscientia Conferences.
Screven, C.G. (1990) ‘Uses of evaluation before, during and after exhibit design.’ *International Laboratory of Visitor Studies Review*, Vol. 1, 36-66.
Tuckey, C.J. (1992) ‘Schoolchildren’s reactions to an interactive science centre.’ *Curator*, Vol. 35, 28-38.
Uzzell, D. (1993) ‘Contrasting psychological perspectives on exhibition evaluation.’ In S. Bicknell and G. Farmelo (eds) *Museum visitor studies in the ’90s*, pp.125-29. London: Science Museum.
Wellington, J. (1989) ‘Attitudes before understanding: The contribution of interactive centres to science education.’ In M.Quin (ed.) *Sharing Science: Issues in the Development of Interactive Science and Technology Centres*, pp 30-2. London: Nuffield Foundation on behalf of the Committee on the Public Understanding of Science.