BLUNTING THE TENSIONS BETWEEN INFORMAL AND FORMAL EDUCATION IN SCIENCE: REFORMING THE RELATIONSHIP BETWEEN THE SCHOOL AND THE SCIENCE MUSEUM IN GREECE

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Abstract – *In this paper, I explore the relationship between formal and informal approaches to science education as mechanisms for dissemination of scientific knowledge. I then posit the combination of specific characteristics from the two approaches into a unified process of non-formal science education. In the second part of the paper, I describe the different types of science museum and present a taxonomy with respect to their educational mission. Finally, I describe the role of the three approaches in the educational system and I illustrate each one with specific examples from science museums.*

From dissemination of scientific knowledge to developing scientific literacy

In recent years, there has been a more frequent use of the term '*scientific literacy*' (or 'scientific culture') both in school environments, and in the literature on public understanding of science. The term has been used in different contexts with different purposes (Bybee, 1997). Beyond the term we can trace the fundamental position that scientific knowledge constitutes a fundamental aspect of our civilization. This position, that scientific knowledge is a *cultural object*, which affects a society trying to function efficiently in a techno-scientific environment, in contrast to simply being a specialized object of teaching, is increasingly adopted by various educational systems and this effort is also beginning to reflect in the science curriculum. The many countries that participate in the OECD/PISA project adopt the following description: 'Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity' (OECD, 1999). Some of the actions supporting this position are the introduction of aspects of the history and philosophy of science in the curriculum, the relevance of curriculum content to problems and issues of everyday life and technology, the development structures of support in science teaching in parallel to the curriculum, and schools opening up to society, particularly to specific organizations aiming at scientific literacy for the wider public.

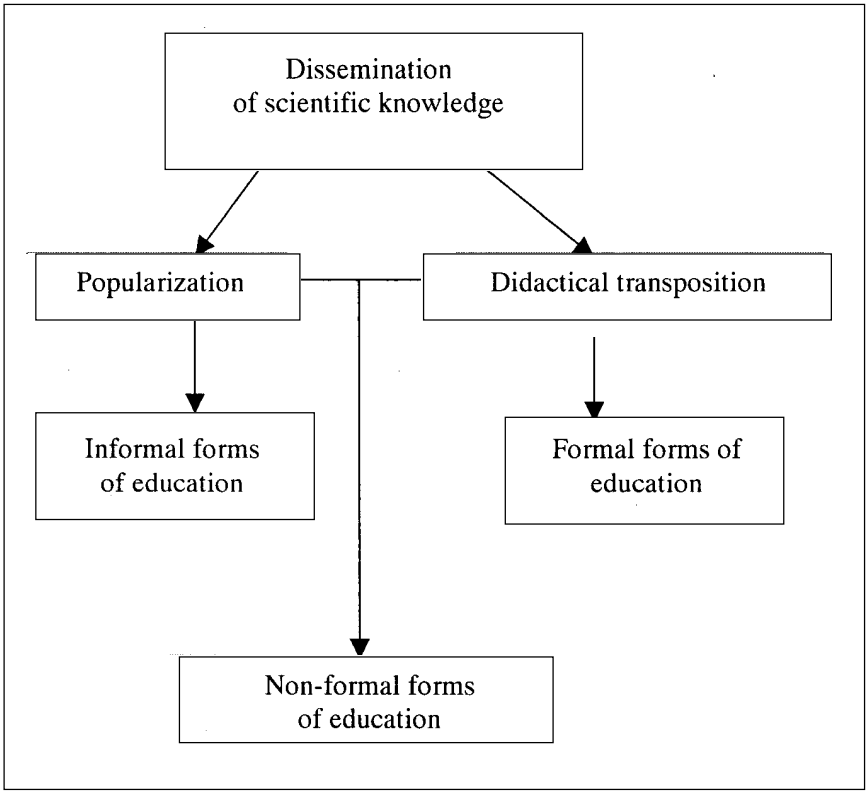
In the present study, we focus on the last action, *schools opening up to society*. Yet, since the school system is not the only factor promoting scientific literacy, it has been noted that the role of formal education, and its relationship with non-formal and informal provision, become more problematic and need further clarification (Hofstein and Rosenfeld, 1996; Jenkins, 1997). In this study, our effort is to clarify the kind and content of the relationship that can be developed amongst a formal educational system and an organization aiming to promote the scientific literacy of the wider public. A science museum can be an example an organization. Specifically the purpose of the study is to describe the nature and characteristics of this relationship, particularly in the context of the Greek environment. We also aim to elucidate ways of making this relationship productive and effective. The Greek context is typical of many countries in the Mediterranean region in that, for many years, it has been a *receiver of scientific knowledge* rather than a *producer*.

Formal and informal forms of education in science

There are two basic mechanisms for the dissemination of scientific knowledge, (Figure 1): P*opularization* of the scientific knowledge and the mechanism of its *didactical transposition*. Popularization is associated with the dissemination of scientific knowledge to the public, whether adults or children. According to Baltas (1984), it constitutes 'an aspect of the entire social function of the scientific institution, one of the ways with which to accomplish the social acceptance of the work and role of the scientist, the ideological legalization not only of the results produced by different sciences, but also of the specific way these are applied in current societies'. Baltas (1984) also claims that, because of this 'ideological' function, popularization appears to transform scientific knowledge to a form of knowledge trying to be attractive and easily understood to the 'non-expert'. Hence, scientific popularization can be defined as the procedure which can achieve the transfer from scientific to everyday language.

The context within which the mechanism of popularization is activated is neither whole nor homogeneous. Popularization can be achieved through the so-called *informal forms of education*. The informal forms of education compose a non-organized and non-systematic field of education relating to everyday experiences and are activated outside the formal educational system. Informal education usually relies on an interaction between own initiative and the efforts of organizations disseminating scientific knowledge, participation is invariably on a voluntarily basis. Typical contexts for the to the popularization of scientific knowledge include the spontaneous engagement with technological phenomena

FIGURE 1: Popularization of the scientific knowledge and the mechanism of its didactical transposition



or problems at home or work, visits to a science museum or to a technology centre, reading scientific articles in newspapers or specialized magazines and watching TV programmes with scientific content or attending popularized lectures by scientists. Table 1 juxtaposes the various characteristics of informal and formal forms of education (Guichard and Martinand, 2000).

Informal forms of education, through the mechanism of popularization, can result in (Escot, 1999): (a) increased sensitivity on issues concerning the physical and technological environment, (b) enhanced interest in a specific topic of science, (c) the possibility of transforming a circumstantial interest in an issue to actually becoming actively engaged in it and (d) the possibilities of creating a personal scheme or even creating the conditions of self-instruction to a certain field of action. However, it still remains open to question whether the mechanism of

TABLE 1: Comparison of the different aspects of formal and informal education

	School education	**Informal forms of education**
Codification	School programme	Not a long-term scheme
Public	Homogeneous group in age	Different public
Conditions	Obligations	Freedom of choice
Time	School time	Free time
Organization / time	Smooth progressive course	Periodic activity
Evaluation	Validation system	Lack of validation system
What is at stake	Exams	Personal culture
Search for	Success	Pleasure and culture

popularization and informal forms of education can achieve what popularization is primarily after: the true dissemination of scientific knowledge. According to Baltas (1984), the procedure with which the transfer from scientific to everyday language is affected, at the same time, abolishes the 'autonomy of meaning' in the scientific language. This may lead the popularized knowledge to paradoxes or to a dead end. In other words, the danger exists that scientific knowledge can appear as a new myth leading to fear, as involving ignorance or negative attitudes.

The difficulties in diffusing scientific knowledge, that are innate to the nature of the mechanism of popularization, can possibly be overcome through the mechanism of didactical transposition (Astofli and Develay, 1989). The didactical transposition constitutes all the modifications over scientific knowledge when this is to become a teaching object within formal education. Regardless of whether it might be an unconscious procedure, as it usually is in practice, or whether the object of teaching results out of systematic didactical analysis, invariably the fundamental components of didactical transposition are *decontextualizing* and *recontextualizing* the scientific knowledge. The object of teaching undergoes decontextualization since knowledge has been extracted from the scientific environment in which it has been built and the actual procedures that led to forming the knowledge in the science field are eliminated. The recontextualization of scientific knowledge relates to the demands and limitations set by the educational context, e.g. the demand for a sequence of lessons within time limits and the priorities of the teacher when conducting the teaching object in the classroom. Thus, the content of scientific concepts can be altered, since they would have to be constrained to a series of units, and their relationships reestablished in order to form a conceptual reference frame work. In this way, a

new artificial scientific frame is shaped concerning the conceptual content, an 'educational epistemology' with totally different features from the one relating to the original scientific knowledge frame. The didactical transposition is relates to the formal forms of education at all levels and for all teachers and students.

The science curriculum constitutes a basic element of structure for all forms of formal education and resumes what popularization fails to accomplish, that is to maintain the coherence and content of science theories, even if stating these theories at a more qualitative level simplifying the mathematical formulation. Of course, in certain cases where the scientific knowledge assumes purely a qualitative character, the limits of popularization and didactical transposition are difficult to discern. Such examples are commonly found in primary schools textbooks or activity books in pre-school education for many years.

The Greek curriculum in science has been dominated by a traditional perception that makes it close to impossible for the students to obtain the scientific knowledge, at least as a cultural object (Koliopoulos and Ravanis, 2000). This perception promotes a didactical transposition of scientific knowledge that is identified by dispersing units of information, extensive mathematical formalism or a 'pseudo-qualitative' approach of the concepts of science, the perception that scientific knowledge comes from experience and the underestimated use of cultural aims (Koliopoulos and Constantinou, 2002).

From the above analysis, it appears that tensions occur amongst formal and informal forms of education, due to distinct educational goals, different mediation strategies and, mostly, due to a *different epistemological approach* in the dissemination of scientific knowledge. These tensions can take a sharp character, as in the case of Greece. In the next section, we discuss how it is possible to blunt these tensions, especially on the epistemological domain.

Non-formal forms of education in science: blunting the tensions

Profound changes have occurred over the last few years, concerning our perceptions of the nature and characteristics of scientific knowledge, and in the content and methods of education. These changes have led to a third field of dissemination of scientific knowledge. I*n this third field, the mechanisms of popularization and didactical transposition of the scientific knowledge appear to be combined*. We shall be using the term '*non-formal forms of education*' to express precisely for this field of dissemination of scientific knowledge. It is worth noting that the terms 'informal forms of education' and 'non-formal forms of education' seem to be employed interchangeably in some of the literature. We don't intend to give here an analytical definition of the term 'non-formal forms of

education' but rather an operational one. However, our approach is closer to that adopted by Evans' who defined non-formal education programmes as those activities organized outside the formal system to form part of the whole integrated concept of an education system (Mehta, 1997). So, non-formal forms of education differ from informal forms in that they involve also the formal educational system. This occurs where the limits of formal forms of education are clearly identified (e.g. the failure of the curriculum to keep up with scientific and technological changes in society, the need for increased motivation of students in science) and there is a need to expand school boundaries into society (e.g. the introduction of environmental education in the curriculum) (Orion and Fortner, 2002). The extent to which the formal system is involved varies substantially depending on the nature and characteristics of organizations offering an environment of informal education.

The non-formal forms of education in science also relate to 'extra-curriculum' activities, which may become part of the curriculum and in a way that enhances the teacher's role (Woolnough, 1994). UNESCO (1986) gives the most well-known classification of extra-curricular activities. They include student participation in science clubs, Science Olympiads, scientific exhibitions, research and project work, visits to science museums and being engaged in their projects, and, last, reading science texts of special and non-special sorts, along with watching TV and radio reports over scientific issues. It is also known that many of the above can be attained at school under the teachers' responsibility. Then, it is no wonder that many students' workshops, science clubs and are scientific exhibitions are found in schools. At the same time one can find appropriate educational projects undertaken by science museums, where the teachers' participation is crucial, since some of the most important are the preparation and follow-up activities in the classroom or the school laboratory before and after a visit. The spectacular techniques often used in science exhibitions and museums could also be practised in the classroom, presenting science as a performance able to arouse an interest, positive attitudes and advanced knowledge. Lastly, the scientific text and films can be used and commented upon during teaching, not only as additional material to be utilized by students' under their own initiative, but also as elements strongly attached to formal teaching.

Can we consider all these activities, regardless of whether they are taking place inside or outside school, as non-formal educational approaches? Not always. The *type of link* between the school environment and the uniqueness of every organization that discriminates scientific knowledge is what determines whether an activity belongs within non-formal forms of education. Therefore, an activity such as a casual or guided visit to a science museum is considered an informal form of education and can be dominated by the mechanism of popularization. Still,

the same activity can be altered into a more substantial form of education if used by the educator in a more coherent educational project in order to activate the mechanism of didactical transposition of scientific knowledge. However, this mechanism cannot be activated independently of the school since the activity needs to be guided by the goals and content of the curriculum, or of the educator, who has to participate in the conceptualization, design and practice of the activity. In this case, we refer to a non-formal form of education. In Table 2 we present examples of informal and non-formal forms of education in science for some of the activities mentioned above.

We would like to posit that non-formal forms of education present an appropriate educational environment for the development of scientific literacy within every field of science. This happens for two reasons: firstly because of the implication of the mechanism of popularization that assists dissemination of scientific knowledge and of the opportunity to freely engage in it, secondly, because of the mechanism of didactical transposition, leading to a systematic approach and evaluation of the school's position on scientific knowledge. In the following paragraphs, we describe the features of a science museum as an organization disseminating scientific knowledge and, also, explore the conditions under which a school's approach to the science museum can lead to non-formal forms of education in science. In other words, we discuss the issue of how the interaction between school and science museum can lead to appropriate environments for the unfolding of scientific literacy.

Science museums and their educational role

The science museum represents a place where knowledge is expanded, primarily appealing to non-experts, who are interested in learning new things, facts and ideas, while of the same time being entertained. What happens within the corridors of such a museum? A slow process of integrating society, culture and science. Hervieu (1997) presents the example of Umberto Eco, who spent more than three years in the 'Musée des Arts et Métiers' in Paris, before writing his famous novel 'Foucault's pendulum'. Bibliographical and empirical research has shown that there is not a single type or unique form of science museum. We have proposed a classification that represents a wide notion of science museums, tending the traditional definition of a museum by ICOM. Our classification has been constructed entirely for educational purposes. Specifically, it aims to highlight the educational role of the science museum from the point of view of the formal educational system. So, this classification provides criteria that a teacher could use to adapt his/her teaching to the objectives and the content of a science

TABLE 2: Examples of informal and non-formal forms of science education

Activity	Institution disseminating scientific knowledge	Informal form of education	Non-formal form of education
Museum activities	Science museums	Simple visit – excursion	Guided visit or educational project of several days
Activities related to science exhibitions	School, science clubs local administration, other organizations	Spontaneous organization without the guidance of specialists or educators	Organization with the educator's assistance or/and within the context of the curriculum
Participation in science labs	School, science clubs local administration, other organizations	Free activities without without the guidance of specialists or educators	Activities guided by specialists or educators or/and within the context of the curriculum
Research and Project work	Scientific and industrial places, school, other educational organizations	Simple visits, writing offhand reports	Writing synthetic/creative works with the educator's guidance or/and within the context of the curriculum
Bibliographical research	Press, radio, TV, websites, school libraries, other public or private libraries	Spontaneous reading audience, watching TV, surfing the Internet, constructing material patterns	Bibliographical research, construction of material patterns with the educator's guidance, use of texts, films, software in formal teaching
Use of spectacles	School, theatre, art studios	Watching theatrical plays, puppet shows, impressive demonstrations, telling and hearing stories	Use of corresponding activities in the process of formal teaching

museum in contrast to an attempt to create a thematic typology of science museums. According to this classification, we can distinguish four categories of science museums (Koliopoulos, 2002):

(a) The *museum-institution*. This category represents a set of physical spaces especially set-up to facilitate people's visits. According to Caro (1996), there are three types of science museums – institutions: (i) the '*exhibition museum*', whose purpose is to gather, save, preserve, indicate and exhibit the natural, technological and industrial background of a science domain. The natural history museums, various university museums in Botany, Zoology, Paleontology and Physics as well as museums with collections of technological items (e.g. school laboratory instrumentation) are all examples of this type of science museum. Two large science museums in Greece, the 'Goulandri Natural History Museum' in Athens and the 'Technical Museum' in Salonica, operate,

mostly, as exhibition museums. (ii) The *'experimental museum'*, which promotes the active participation of visitors and attempts to familiarize them with the scientific knowledge through interaction, *experiencing* and *experimenting*. The effort here is for scientific knowledge to be appreciated through movement experimentation and sensory participation, the aim is to attain a better integration of the traditional science fields (Mechanics, Electromagnetism, Optics etc.) than is currently possible within school education. This refers to a type of museum attaining an educational character that can act side-by-side and even complementary to formal science education. Emphasis is given to natural phenomena and activity spaces rather than the exhibits themselves. The activity spaces usually have the form of galleries, places of experiment demonstrations (usually small amphitheaters), places for hands-on experiments or even spaces resembling to science labs. The 'Palais de la Découverte' in France and the 'Exploratorium' in the USA are typical examples of this kind of museum. (iii) The '*cultural centre*'. This refers to an open cultural center, where the visitor can approach the context of science without fearing that it might be too sophisticated for him/her. Exhibits and activities place emphasis on the social applications of science and technology. The aim is for the public to develop a positive attitude towards science and technology through appreciating their social utility. Scientific research is linked to industrial activity and, in general, the effort is to make the visitor aware of the scientific, economic, technological and cultural dimensions of the scientific enterprise. Instead of the traditional disciplinary organization, principally, one finds that cultural centers are organized along applied themes, such as Transportation, Communications, Space etc. 'Cité des Sciences et de l'Industrie (La Vilette)' in France is a typical example of this kind of museum. Experimental museums and cultural centers do not currently appear as autonomous organizations in Greece.

(b) *The virtual museum*. The development of new technologies, especially of the Internet, over the last decade has had a strong influence on science museums. Numerous museum - institutions have created their own Internet site to provide information on the available exhibits. Such sites can be used in two ways: (i) as an *information pool* and (ii) as *communicative means for developing collaboration*. Still, some researchers suggest the complete abolition or severe curtailment of big science museum – institutions on the grounds that they are unprofitable, inefficient organizations with inflexible administrative structures. In their place they suggest the establishment of autonomous virtual environments, liberated from the confinements of the buildings, geographical area and propriety establishment. Virtual museums are not currently developed in Greece, which

would be anticipated considering the existence of science museum–institutions is limited. This presents an opportunity for developing virtual sites for disseminating scientific knowledge independently of museum-institution.

(c) *The children's museum*. The children's museum is a place specially designated for the needs, interests, knowledge and psychokinetic abilities of young children. Traditional statements of the type 'look but do not touch' are surely unfit for children who prefer to learn through hands-on experimentation with real and virtual objects. Science museums presenting *interactive exhibits* and *experimental activities* are already close to the child's abilities and demands. However, certain institutions have proceeded in establishing autonomous exhibition areas, with specially structured material, instead of a simple sequence of interactive exhibits. These exhibitions are also suitable for pre-elementary children, which is not the case with 'experimental' museums. One of the best *science museums for children* is the 'Cité des Enfants', which occupies a large space in 'Cité des Sciences et de l'Industrie (La Vilette)'. In Greece we do not currently have such a museum but one can find some interesting science activities for children in other museums.

(d) *The museum-in situ*. This category includes science museums that only take meaning within the physical and human environment in which they were developed. A typical representative of this type of museum is the *open-space museum*. Such museums operate through functional connection with their locations and their historical context. At the same time, these locations are viewed as part of the cultural heritage and are, therefore, protected. Examples of open-space museums are the museums of moving water and museums near locations with interesting geological history. Another type of museum-in situ is the *university museum*. This includes real or virtual science museums run by one or more universities which serve part pf the research and didactical missions of these institutions. Finally, in this category of museums we could include the operating *industrial units*, which provide museum items, these are typically places of exhibition or purposeful educational activities related to procedures of transformation of scientific knowledge into the development of technological equipment. The apparent lack of science museum – institutions in Greece (and in many other countries of the Mediterranean basin- Demopoulos, 2002) makes these industrial units useful tools for any educator, whose aim is to promote the scientific and technological literacy of the students. In the same type of museum, one could also classify the science activities provided by different thematic museums. These activities, like conserving works of art or activities pertaining to folkloric approaches cannot be detached from the environment of their

development. For instance, the 'Greek Byzantine Museum' includes activities familiarizing the public with preservation methods for works of the Byzantine and meta-Byzantine era. In Greece, the science museum-in situ is, perhaps, the type of science museum with the greatest originality. This is because it potentially connects the development of scientific literacy, with local scientific and technological activity and not with items or ideas produced elsewhere.

In conclusion, despite the absence of a science tradition, the science museum in Greece exists. It can appear in various forms and become a source of inspiration for the design of non-formal types of science education at all levels. In the next section, we will specifically discuss how this objective can be achieved.

The interaction between science museum and school as a context for non-formal education: the potentials for Greek education

There are mainly two factors that influence the objectives and content of educational activities that can facilitate the synergy between school and museum. The first factor is the scope and variety of objectives that the specific science museum has adopted. It is for this factor that the analysis outlined in the previous sections can be useful to the educator. The second crucial factor relates to the *restrictions* imposed by the science curriculum. The school and the educators would have to handle these restrictions and correlate them with the opportunities provided by the science museum. The present article negotiates on the operation and synthesis framework of the two factors, from the school and educators' perspective.

A basic problem associated with the nature and characteristics of non-formal forms of education is whether and how the students can demonstrate progress in their knowledge in relation to the goals of the curriculum while visiting the exhibits and spaces of a science museum. Much of the existing literature concerning the educational role of the scientific museum focuses on motivation and learning in informal contexts such as scientific exhibitions or interactive exhibits (Ramey-Gassert et al., 1994; Science Education, 1997). These contexts have been related primarily with the '*casual visit*' or the '*guided visit*' (Koliopoulos, 2002). The casual visit is the most common method of approaching the science museum. It is hard to find a suitable educational context for developing a non-formal form of science education designated for the casual visit. The school and the educator have to try immensely to organize and adjust the visit to the school's curriculum framework. Usually, this does not occur and consequently the casual visit in a science museum results in a lost educational and teaching opportunity for the students, mainly because a combination of this lack of reference and sterile activism (Tunnicliffe et al., 1997; Griffin and Symington, 1997). On the other hand, many museums make an effort to substitute the casual visit with the guided one, they usually approach this by encouraging schools to

participate in specific projects organized by the museum. In the guided visit, the science museum assumes the leading educational initiative, in which case the actions of the educator are restricted to those of an escort or a person dealing with organizational issues and practical problems. In this context, any incompatibility of knowledge goals between the educational projects of the museum and the school curriculum can lead to stressful situations for school and museums alike.

Is it possible then to think of an appropriate educational environment for the enhancement of non-formal forms of education in the context of a school visit to a science museum? This environment that we would like to call a '*complete educational project*' must result from close cooperation between the science museum and the school. It must not also be identified and reduced to an isolated visit to the museum's spaces. It consists of a complete dynamical procedure placing an emphasis on the phases preceding and following the visit. Both at the cognitive or the emotional level, the phase before the visit is quite important, bearing in mind that the educator, besides organizing the visit, must choose a topic proposed by the museum and *adjust it to the needs of the existing school curriculum and the cognitive abilities and interests of their students*. The phase after the visit is equally important. During this phase, there can be an evaluation of the project and construction of new knowledge based on the interests and emotions awaken by the visit. Essentially, this is the place that can *transform the popularized knowledge provided by the museum into a more structured and functional form*. In the complete educational project, the school and educator's role is to activate a procedure of re-contextualizing the scientific knowledge within the desired didactical transposition. This cannot be achieved by the museum. On the other hand, the science museum's contribution is that the students will experiment into new learning situations due to the variety of sources provided and will attain a better comprehension of the scientific, technological and industrial environment. The complete educational project brings us a step closer to achieving a wide range of cognitive, emotional and kinesthetic objectives, which promote the development of scientific literacy, since there is enough time for the mechanisms of popularization and didactical transposition to operate simultaneously.

The complete educational project can take several forms. In the following paragraph we will give two examples. The first example concerns the '*classe Villette*' project administered by the 'Cité des Sciences et de l' Industrie'. In this case, a group of Greek students visited and worked in the museum for a week undertaking a well-structured project. Educational projects, such as the 'classe Villette' project, are administered by local or international 'science museums–institutions' and engage teachers and students in long-term activities about a science theme or topic. The teacher is responsible to relate these activities with the

curriculum. The second example concerns an educational project on the production of wine that was designed by a group of researchers in the domain of scientific Museology and educators in early childhood education. This project, which is still in progress, includes activities before, during and after a visit by the children to the winery 'Achaia Clauss' of Patras, and aims to engage children in a process of actively changing their views about wine production. In this case, the school uses the 'museum-in situ' as a familiar and traditional place to establish valid scientific knowledge.

Epilogue

It is only in the last decade that the relationship between formal and informal forms of education in science has become an object of research in Science Education and an academic subject of teaching. It is difficult for someone to identify consolidated methodologies or widely accepted theoretical frameworks to direct research or teaching in this area. Thus, this paper represents than a first attempt at describing an educational environment that is likely to create real interest and operational knowledge in science in the context of developing scientific literacy. We have traced epistemological differences between formal and informal forms of education in science and so introduced the term 'non-formal forms of education' to describe the type of educational environment within which there has been noted an excess of obstacles proceeding out of these differences. Hence, a relationship is established between the informal and formal character of education leading to scientific literacy development. Through a case study concerning the relationship of science museum and school, we have claimed that this relationship can become effective if it can take the form of a complete educational project, in which case the science museum and school can cooperate as equal partners. However, it must be remarked that the development of this relationship cannot be accomplished outside the cultural context it operates. For instance, the science museum concept is not homogeneous and it is not possible to assume the same meaning in a country that traditionally produces science as in a country, such as Greece, which for years has been receiving scientific knowledge from elsewhere. That is the reason why the desired scientific literacy is most certainly affected by the given cultural context.

Finally, this article raises more problems, than giving answers. This is indicative of the stage of development of this area of educational research. University research and teaching in the Educational Departments can help to further clarify the hypothesis that non-formal educational environments can blunt the tensions between formal and informal forms of education and lead to the

creation more of scientifically literate students and teachers. Specifically, a question, that remains open for future research is the following: What are the concrete cognitive and emotional outcomes of applying non-formal forms of science education in comparison to pure formal or informal forma of education forms? In the Mediterranean region, an interesting study could be designed aiming to explore differences and similarities in this topic between on the one hand countries having a rich tradition in science production and displaying many science museums and, on the other hand, countries that have been more on the receiving end science.

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