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THE DISSEMINATION OF ELEMENTS OF SCIENTIFIC KNOWLEDGE IN ARCHAEOLOGICAL MUSEUMS IN GREECE: SOCIO-CULTURAL, EPISTEMOLOGICAL AND COMMUNICATIONAL/EDUCATIONAL ASPECTS

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ABSTRACT

This article examines the potentiality of the dissemination of natural sciences not in the usual science museum environment, but in the archaeological museum. The aim is to highlight the existing interfaces between the fields of archaeology and the natural sciences in the setting of a Greek archaeological museum so that its exhibition space can serve as a field for non-formal education for dissemination of natural sciences as well. Starting with the investigation of the necessity of such a choice, which follows the international trend of interdisciplinary interpretation of museum collections and dialogues between permanent collections and temporary exhibitions of different disciplines, it identifies the following four interfaces: a) archaeometry, b) conservation, c) ancient Greek science and d) ancient Greek technology and art. Finally, it examines the feasibility of designing a 'science educational islet', a museum structure mainly addressed at school groups that embodies the relationship between natural sciences and archaeology as a result of both didactic and museographic transposition simultaneously.

KEYWORDS: Museology, didactic transposition, museographic transposition, archaeological museum, science communication, interdisciplinarity, educational role of museum

1. INTRODUCTION

Governments and institutions project the importance of science understanding and scientific research. Museums of Science and Technology and Natural History museums are the non-formal educational institutions traditionally responsible for the dissemination of the natural sciences, due to the nature of their collections (Dierking et al., 2003; Filippoupoliti & Koliopoulos, 2014; Schiele, 2001; Shaby, Assaraf, & Tal, 2017). This paper examines whether and how scientific content can be disseminated in a different museum setting, that of the archaeological museum.

Based on their collections, the museums are generally divided into categories such as archaeological museums, museums of science and technology, natural history, art, etc. (Poulot, 2009), following the traditional thematic typology, as it is structured around the triptych Art-Science-History (Edson & Dean, 1996) and reflect more general cultural transformations of scientific circles (Gob & Drouguet, 2003; Schaer, 1993). Archaeological museums collect, study and exhibit authentic ancient artifacts and human remains (Bounia, 2004).

However, the value of objects as exhibits consists of many layers of interpretation (Hooper-Greenhill, 1992; Lord & Lord, 1997; Pearce, 1995), that also includes the cultural dimension of natural sciences (Levy-Leblond, 2004; Meunier & Luckerhoff, 2012). Museums, having evolved into wider cultural institutions, with specialized scientific staff from other disciplines trying to provide a holistic understanding of the natural world (Olmi, 1985), made the scope for interpreting tangible and intangible culture and human remains wider (Desvallées & Mairesse, 2014). Museum pluralism in terms of architecture, administration, and function enhances the symbolic nature and social dimension of the museum's mission, beyond the traditional obligations of preserving, validating and enriching cultural heritage (Ambrose & Paine, 2012; Burton & Scott, 2007; Grenier, 2013; Tobelem, 2010). Both the recent modifications of the definition from the International Council of Museums and the hierarchy of museums suggested by the American Alliance of Museums reflect the shift in interest in all ways of interpreting collections, education and learning. More and more new fields open up because of new ideas in contemporary museums (Overskaug, 2012).

In this context, our article examines a) the epistemological basis for the existing interdisciplinary relationship between the archaeological museum and the natural sciences; and b) the feasibility of designing an exhibition microenvironment, an 'islet' that embodies this relationship, accompanied by an educational program for school groups.

2. THE SOCIOCULTURAL ARGUMENT: IS THE INTERPRETATION OF EXHIBITS OF AN ARCHAEOLOGICAL MUSEUM IN THE LIGHT OF THE NATURAL SCIENCES NECESSARY?

The traditionally closed relationship between the dissemination of natural sciences and science museums or centers is stated by the distinct subcategory of '*Scientific Museology*' as the scientific area of the educational phenomena take place in science museums (Achiam & Marandino, 2014; Clement, 1993; Guichard & Martinand, 2000; Schiele & Koster, 1998). However, relations of different scientific fields can be revealed in all types of museum exhibitions. Interdisciplinary exhibitions are organized in different types of museums (e.g. at the Museum of Modern Art and the Metropolitan Museum of Art[1]), where art is co-exhibited with technological tools, natural history collections and similar (Abadi, 2008; Blatchford & Blyth, 2019; Filippoupoliti, 2010). In this type of exhibition design, even in the archaeological museum the cultural aspect of science can be highlighted (Copley, 2010). Such an approach aims to represent a concept, a situation or a problem in an interdisciplinary way through the convergence of more sciences (Fourez, 1997; Maingain, Dufour, & Fourez, 2002).

2.1 Dissemination of science knowledge in different kinds of museums

Although a classic art gallery, the Pinacotheca di Brera in Milan – Italy[2], has converted one exhibition hall into a visible conservation workshop. The presence of the conservation lab projects one of the museum's traditionally invisible functions and not only allows, but also encourages the visitors to realize the bond between the materiality of the artwork and the modern scientific knowledge of the natural sciences required for its preservation and conservation. The Van Gogh Museum in Amsterdam – Netherlands[3], is a similar example where a small part of the exhibition is devoted to the techniques used for both conservation and deep examination of works to certify or not their authenticity (mainly X-rays). The steps of the conservation process are organically integrated into the exhibition and are accompanied by interpretive tools such as explanatory texts and microscope pictures. On the other side of the Atlantic, the Dallas Museum of Art, Texas – U.S.A.[4] goes a step further. There, the conservation lab is not just a closed room that allows only visual contact, but is equal, autonomous but integral, part of the museum's exhibition, that is accompanied by educational activities. The intention of this museum is clear in the wording of the mission statement.

'Through this unique component of public access, the DMA aims to provide visitors with a deeper understanding of how works in the collection were made, what has happened to them since they left the artists' hands, and how the Museum ensures that they are preserved for the future.'[5]

Le Grand Musée du Parfum in Paris – France[6] is an example of a thematic museum whose narration is based on the timeline of perfumery. Moreover, one of its exhibition showcases is dedicated to explaining the smell as a biochemical process in chemistry terms. However, knowledge of 'reading' chemicals is required for an in-depth understanding.

2.2 Dissemination of science knowledge in science museums/centers via interdisciplinary approaches

Based on the belief that some of the objectives of science interdisciplinarity can best be achieved in museum-like settings where students and other visitor groups can gain first-hand experience with the fabric of natural phenomena (Oppenheimer, 1972), the Exploratorium in San Francisco, the pioneer science center in the USA and internationally, designed its exhibition space in such a way that art and an atmosphere of playfulness enhance the mechanisms of human sensory perception. The biggest science museum in Europe, the Cité des Sciences et de l'Industrie in Paris – France, with its exhibition 'Tranches de vie au Moyen Age'[7], presents various aspects of the life of this particular historical period and socio-cultural context. Thus, technologies of medieval times that can imply natural science elements as part of the history of science coexist with the art and aesthetics of the time. In fact, the exhibition does not differ from modern exhibitions of history museums that offer opportunities for interaction and entertainment with exhibits designed specifically for younger children. The choice of a science and technology institution to converse with history is what matters. Indeed, very often, many science museums introduce artists' works, either in solo exhibitions or as part of science exhibitions. For example, in the lecture 'Art and Astronomy: A Meeting of Two Worlds', the artist Apostolos Kilesopoulos and the professor of Astrophysics at the Aristotle University of Thessaloniki Ioannis Seradakis conducted an original dialogue attempting to showcase the creative synergy between science and art, on the occasion of an art exhibition with paintings with constellations, nebulae and sky maps in 2018 at the Teloglion Foundation of Art (Thessaloniki-Greece). Besides, even Einstein's physics touches on profound existential questions that are also dwelt upon in the arts (Østergaard, 2006). Østergaard reminds us the opinion of many artists and scientists that:

'Art and science can be regarded as two different but complementary modes of making sense of humankind's relation to the world and nature. [...] This allows a double perspective on art and science as different in regard to activity and language, but similar in regard to their mutually complementing characters.'

(Østergaard 2006 p. 11)

However, these practices need to be cautious, as new questions, concerns and further complexities are raised (Arapaki & Koliopoulos, 2011). For Redler (2009), referring to London's Science Museum, looking at art and science together is not always a comfortable project. She finds out that:

'Although Science Museum Art Projects started as a quirky, experimental sideline aimed at shaking up the Museum and its visitors' assumptions but has now become a fundamental means by which the Science Museum chooses to represent the impact of science, medicine, engineering and technology on peoples' everyday lives.'

(Redler 2009, p. 1)

In other words, she argues that contemporary museums should reflect the culture of our time becoming vital landmarks through the histories we have the privilege to be guardians of.

2.3 Dissemination of science knowledge in archaeological museums and sites

In the permanent exhibition at the archaeological Musée gallo-romain Lugdunum in Lyon – France, not only the historical context of Roman constructions and especially the aqueducts are presented, but also their function and construction principles. However, despite the fact that archaeological remains are framed by mock-ups of these aqueducts that simulate their operation by moving water through pipes on a button click, knowledge of the theory of the communicating vessels and Bernoulli's fundamental theory for hydrodynamics is required. In the temporary exhibition of the same museum, entitled 'L' aqua, l' invention de Romains'[8], reproductions of the hydraulic systems or related instruments used by the Roman engineers are accompanied by pictures, videos and texts, which provide a first-level explanation of the relevant natural laws.

The permanent displays at the Acropolis Museum[9] in Athens – Greece are based on the concept of 'masterpieces', without offering a multidimensional interpretative framework. This changed after the Symposium 'About the Acropolis Museum: Ideology, Museology, Architecture' where such omissions were noted. As a result, models, copies and digital representations were added, serving at least as hints for the technological and scientific interpretation of the historical period the collections were designed and constructed. A new room called 'Art Lab' showcases ancient technology, the creation of works of art and the production of copies.

The travelling exhibition entitled 'Myrtis, face to face with the past'[10], designed in 2010 by a team from the National and Kapodistrian University of Athens - Greece, was different from any other permanent or temporary archaeological museum exhibition in Greece until then. The aim of the exhibition was to project the excavation findings in a way that related scientific theories, practices and technological tools of the modern era were revealed. The exhibition was developed around two original objects only: a. the skull of the deceased person, which bore such integrity of the denture that made it possible to identify the cause of death and to be associated with the plague of 5th century BC.; and b. the face model, that was created approximately, based on anthropological features and geographical data. The aim of the exhibition was to narrate the interdisciplinary process from excavation to exhibition, mainly highlighting the fact that conclusions about the recent and distant past are the result of the collaboration of many scientists of different disciplines.

During the period 2012 - 2014, the National Archaeological Museum's, Athens – Greece, exhibition about 'The Mechanism of Antikythera'[11] showed extensively not only the discovery story, but also the efforts of an international team of scientists to understand the mechanism's design and functions. The visitor could watch videos in which experts explained the movements of the celestial bodies that the mechanism was able to predict, but this required astrophysics and astronomy knowledge that was not provided in the exhibition text.

Indeed, research on the central philosophy and interpretative approach of the exhibition in selected Greek archaeological museums found that references to museological terms were not always implemented in practice (Gazi, 2007). In spite of the stereotypical rhetoric about new museological concepts and requirements, they are neither precisely defined nor associated with specific interpretative decisions within the exhibition, concerning either the narrative structure or the variety of appropriate media to serve the needs of different visitor groups. Thus, despite their desire to belong to the 'third generation' of museums, they practically remain closer to the characteristics of the 'first generation' (Kjeldbaek, 2001; Friedman, 2010).

According to a survey in UK archaeology museums about their scientific content, most of the respondents recognized the potential for presenting archaeological science in an accessible and meaningful manner:

> *'With many governments placing increasing attention on fostering a greater interest in science, archaeology museums possess a unique opportunity using human focused stories as the hook. Perhaps partly due to historical reasons, natural history museums (and their visitors) view their collections as primarily scientific ones. But Archaeology naturally lends itself to more human-centered narratives.'*
>
> (Copley 2010, p. 396)

To summarize, there is a strong intention to integrate natural sciences content into different museum narratives. But further research on the dissemination of science knowledge in archaeological museums is required.

3. THE EPISTEMOLOGICAL ARGUMENT: IS THERE AN INTERDISCIPLINARY RELATIONSHIP BETWEEN ARCHAEOLOGY AND THE NATURAL SCIENCES?

Despite the different historiographical approaches from time to time, the general purpose of History is the attempt to reconstruct and interpret the past (Renfrew & Bahn, 1991). Traditionally, in Greece the discipline of Archeology lies under the historical sciences umbrella and focuses on the study of ancient artifacts and the remains of humans. However, it has evolved so that its conceptual framework encompasses much more distinct methodologies than history or anthropology (Taylor, 1948) and specialized techniques. However, archaeological museums traditionally house the dominant ideological conception of the supremacy of the national identity corresponding to the aesthetic and technical quality of the artifacts (e.g. Gazi, 2007). In countries like Greece, where the majority of public collections are archaeological ones, archaeological museums have maintained that idea.

Historically, the gathering, protection and preservation of antiquities has been a primary concern of Greek state, central or local archaeological museums (the latter are usually part of the archaeological site) in order to preserve ancient heritage and thus consolidate national identity. In 1829 the first Archaeological Museum of the newly established Greek State was created (first on Aegina island and then in Athens) followed by the foundation of the Central Archaeological Service in 1833. The focus of archaeological museums in preserving the findings of excavations as evidence of the people who made them detaches them from their lives after excavation. This second part of their lives is inextricably linked to the natural sciences, although it is not usually part of the narration of the museum exhibition.

3.1. Natural Sciences as reference knowledge in the archaeological museum: nature and characteristics

Examination of the literature as below reveals that the interdisciplinary relationship between archeological museum collections and the natural sciences exists in four cases explained below. This relationship does not stem from the protection and conservation of antiquities stored and / or exhibited in archaeological museums, but also because of the involvement of other relevant scientific fields in the interpretation of archaeological exhibits. More specifically we could identify the following fields: (a) archaeometry, (b) conservation, (c) ancient Greek science and (d) ancient Greek technology and art (Figure 1). It seems that exhibits of an archaeological museum are potentially suitable material for the dissemination of the knowledge that comes from clearly defined fields of interdisciplinary knowledge of reference.

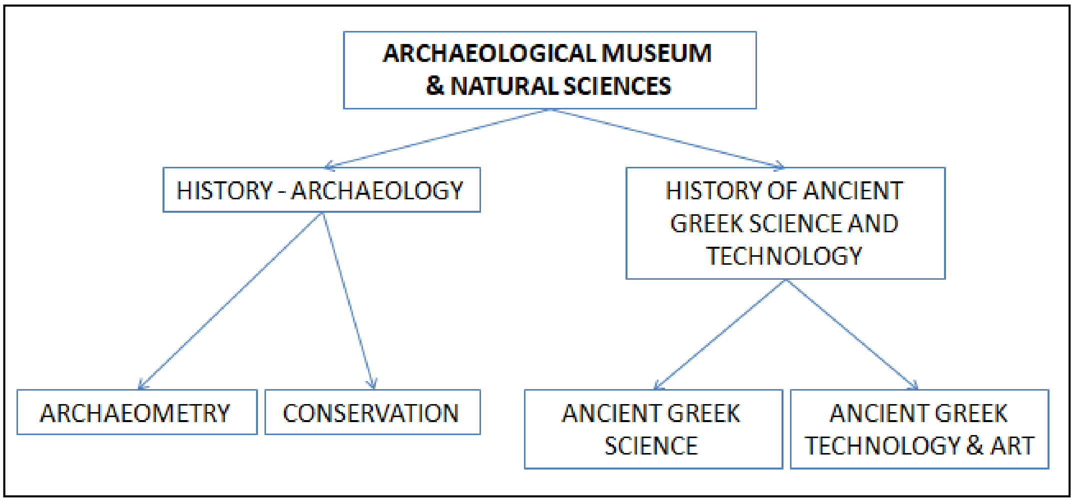

Figure 1: Scientific fields as interfaces between archaeological collections and the natural sciences

3.2. History – Archaeology

Archaeometry

Archaeometry is a set of concepts and methods of natural sciences that help archaeologists study and interpret ancient monuments and artifacts and therefore human civilizations (Leute, 1987; Liritzis et al., 2020). As Liritzis et al. state:

> *'Archaeometry is a scientifically established international discipline that investigates scientific issues of cultural heritage; it is a multidisciplinary science that develops research and solves archaeological problems. […] Archaeometry results consist of data (such as graphs, statistical information, etc.) which simplify and facilitate the possibility of comparing cultural samples and retrieving maximal information from their micro scale, thus conducting safe conclusions, which can be used globally by researchers, scientists and government officials.'*
>
> (Liritzis et al. 2020, p. 81)

Archaeometry consists of a wide range of scientific fields that have emerged from the need to solve archaeological research problems concerning the study and reconstitution of the paleo-environment and the paleo-ecosystem in different eras and the identification of economic, social or architectural structures of the past. In particular, 'dating, composition and origin of materials' (Artioli, 2010; BUP, 2019) can be privileged fields of interpretation for archaeological collections consisting mainly of autonomous archaeological units (e.g. ceramic, metallic or wooden objects). The suitability of archaeometry data (such as graphs, statistical information, etc.) and potentiality of dissemination of science are mentioned recently even as factors for sustainability since cultural heritage is a strong part of community identities (Liritzis & Korka 2019). The introduction of these three specific fields of archaeological knowledge seems to be a methodologically appropriate and practically feasible project that fits into the specificity of the exhibits of an archaeological museum (Georgopoulou, Meunier, & Koliopoulos, 2020).

We can distinguish three components from which archaeometric knowledge is generally constituted: (a) the conceptual component, e.g. the conceptual networks for radiocarbon (^{14}C) dating (nuclear reactions, radioactive isotopes, half-time of radioactive nuclides, etc.) (Liritzis et al., 2020), (b) the methodological component which includes methodological strategies, techniques and laboratory equipment needed to answer questions of archaeological research, e.g. hypothesis formulation, physical, chemical or radiochemical techniques concerning qualitative and quantitative analysis of ceramic objects and pigments to determine their origin or their artistic value and related technological equipment (Maggetti, 2001; Mommsen, 2001), and(c) the cultural component which includes elements of historical evolution of archaeometric methods or the realization of valorization of cultural heritage assets, which make Archaeometry as one of the top priorities for sustainability on national and regional levels (Liritzis et al., 2020).

Conservation

Conservation of antiquities and works of art is an applied scientific field that mainly studies the mechanisms of material damage with the aim of applying appropriate methods for their preservation (Amoroso, Fassina, & Lewin, 1983; Lampropoulos, 2017a, 2017b). This field can be considered part of the broader field of Archaeometry. According to Liritzis et al.

> *'Modern conservation science has been developed following, in general, two main streams …: (i) the development of methods for the identification of materials in objects of cultural and artistic value and the investigation and monitoring of their degradation processes, developed because of ageing. (ii) The research for new scientific methods and materials for effective and sustainable interventive and preventive conservation strategies.'*
>
> (Liritzis et al. 2020, p. 74-75)

These two streams are inter-connected since before conservation process (which often requires the application of sophisticated and high-tech scientific methods), it is important to know the materials of the object and its degradation processes. This interdisciplinary knowledge usually requires interdisciplinary working groups (Korres, 1991). The question is, though, what kind of interdisciplinary knowledge is suitable for an archaeological museum. Because the questions / problems that lead to the application of this knowledge are mainly technological rather than scientific (i.e. the use of scientific knowledge serves an activity aimed at producing a repaired cultural product), this knowledge does not seem to gain priority in its introduction to archaeological museums, unless these museums have set up conservation laboratories in exhibition spaces for the purpose of disseminating this specialized knowledge.

3.3. History of Ancient Greek Science and Technology

Ancient Greek Science

Ancient Greek philosophy and science can be studied even by ignoring modern science, in its historical dimension (Lindberg, 1992; Lloyd, 2012). In the preface of his book 'Early Greek Science' G.E.R. Lloyd notes that:

> *'Science is a modern category, not an ancient one: there is no term that is exactly equivalent to … 'science' in Greek. The terms philosophia (love of wisdom, philosophy), episteme (knowledge), theoria (contemplation, speculation) and peri physeos historia (inquiry concerning nature) are each used in particular contexts where the translation 'science' is natural and not misleading. But although these terms may be used to refer to certain intellectual disciplines which we should think as scientific, each of them means something quite different from our own term 'science''.*
>
> (Lloyd 2012, p. 9)

At the same time, it is found that the connection of the field of ancient Greek science with modern science is the subject of research of modern scientific fields of History and Philosophy of Natural Sciences. Description of the conflict between the Aristotelian version and the Galilean (modern) version of science or rejection of Ptolemaic astronomical model as a characteristic case of changing scientific paradigm (Kuhn, 1970) are typical examples of the involvement of ancient Greek science in the study and dissemination of modern scientific knowledge. It has been pointed out that the History and Philosophy of Science is scientific knowledge which can be introduced into museums and science centers either as exhibits and communicational element or as educational tool (Filippoupoliti & Koliopoulos, 2014; Koliopoulos & Filippoupoliti, 2014). Consequently, ancient Greek science as an element of the History and Philosophy of natural sciences could be a kind of conceptual bridge between archaeological museum exhibits related to ancient Greek science and modern scientific knowledge. It remains to be investigated whether this epistemological possibility can be transformed into a museological feasibility. In practice, the transformation doesn't seem obviously implementable in a museum context since, usually, ancient Greek science is related more with texts (i.e. ancient literature) than objects like excavation findings.

Ancient Greek Technology and Art

Unlike ancient Greek science, ancient Greek technology relates primarily to ancient Greek objects or collections (Liritzis & Panou, 2017) and therefore constitutes a potential conceptual bridge between archaeological museum exhibits and contemporary scientific knowledge. Archaeological museums in Greece tend to avoid exhibiting either authentic or reproductions of objects along with their technological scientific interpretation (e.g. clay technology for ceramic crafts). The 'Antikythera Mechanism', an advanced astrolabe from circa 100BC, with bronze gears for astronomical calculations based on the cycles of the Solar System (Jones, 2017) is a notable exception, as explained above. The organizers of a scientific symposium dedicated to the study of the Antikythera Mechanism describe the aims of the symposium as follows:

> *'In June 2012 we plan to hold a workshop linking modern and ancient astronomical technology through the Antikythera theme. We will explore the evolution of astrometry and computing from ancient Greece to the present, we will compare the technologies used to unravel the secrets of the Antikythera mechanism with the imaging tools of modern astronomy, and most importantly, as we pursue our vision of an exciting scientific future with telescopes such as the Square Kilometer Array we can reflect on why the Antikythera technology was lost for more than a thousand years and whether this can happen again'.* [12]

The aims above express the interdisciplinary nature of knowledge. These objectives reflect the interdisciplinary character of knowledge that can be developed in the investigation and interpretation of the Antikythera Mechanism, but also any other technological object of antiquity. An important dimension, for example, of this knowledge is the modern scientific knowledge needed to interpret the structure and content of an (archaeological) technological artifact (Ekers, 2012).

Ancient Greek art as a conceptual bridge between archaeological exhibits and modern scientific knowledge has more to do with the history of technology than with the history of art. Certainly the aesthetic value of archaeological objects is the main subject of research of the History of Art in combination with the science of Archaeology, and this is the norm for most Greek archaeological museums (Smith & Planzos, 2012; Stansbury-O'Donnel, 2015). In some cases, however, it seems possible to combine art, technology and modern science since this relation has a social dimension, not as a distinct academic field but in occasions such as art exhibitions (Blatchford & Blyth, 2019) art conservation (Mohen, 1996), epistemology (Lévy-Leblond, 2010; Panofsky, 1956) and education (Science Art & Technology[13]; (Arapaki & Koliopoulos, 2011)). From the above it can be concluded that it is possible to combine ancient Greek art, ancient or modern technology and modern science in an archaeological museum, under the condition that a suitable interpretive/educational museological narrative is developed in order to highlight the necessity of this conjunction.

4. THE COMMUNICATIONAL-EDUCATIONAL ARGUMENT: CAN SCIENTIFIC KNOWLEDGE BE INTRODUCED INTO THE ARCHAEOLOGICAL MUSEUM AS AN EXHIBIT/COMMUNICATIONAL ELEMENT OR /AND AS AN EDUCATIONAL TOOL?

Reference scientific knowledge (that is born and operates in its production spaces), when converted into knowledge for dissemination and education in museums, necessarily undergoes an appropriate transformation to keep up with the museum aims and the profile of the visitors (general public, the school community, special groups). School groups (especially of primary and secondary schools) are among the most frequent visitors to Greek archaeological museums. Thus, our study focuses on this audience. This transformation may take various forms being either an exhibition/communication object (exhibit, exhibit unit, exhibition) or a museum educational tool (educational programs, seminars, cultural events).

Next, after outlining the nature and characteristics of the various types of transformation that scientific knowledge can receive in its designated public spaces, that is in science museums and centers, we will proceed with the formulation of a proposal for whether or not the interdisciplinary scientific knowledge as described in Section 3 is possible to be communicated and transformed in an archaeological museum setting.

4.1 Scientific knowledge in museums as exhibit/communicational element and/or as educational tool

Guichard & Martinand (2000) defend the idea that a new field of knowledge, that of Science Media ('*Médiatique des sciences*'), must be developed for popular media such as museum exhibitions. It integrates characteristics (forms, publics, etc.), objectives, issues and methods (organization, dissemination, etc.) of the science popularization. Multiplicity of media used, and target audiences determine the specific issues of science. Guichard & Martinand have developed a theoretical framework to explain the nature and characteristics of transformation of scientific knowledge forms for the design and implementation of an exhibition within the science museum or center. They, inter alia, introduce the concept of 'mediating transposition' in which scientific knowledge and scientific objects are transformed into (a) scientific content (*contenu scientifique*), (b) media device (*dispositif médiatique*) and (c) media staging (*mise en scène*). In particular, they argue (p. 130-131):

> *'There is destruction of the message and restructuring in another form and in another context ... The media device is a new creation, a recontextualization, an objectification and a staging of knowledge, in which the staging or image (scenography, design, model, etc.) are of capital importance* '. [Free translation by authors]

Other researchers used the similar concept of *museographic transposition* to describe the constraints and opportunities that influence the presentation and dissemination of science in museums (Achiam & Marandino, 2014; Mortensen, 2010; Simonneaux & Jacobi, 1997). Museographic transposition or more generally the production of a specific discourse of the exhibition media firstly falls within a communicational rationale, depending on the preferred media. The work of the museographer makes it possible to stage objects or to propose devices intended to facilitate the appropriation of the knowledge disseminated by these means.

Consequently, we believe that the problem of introducing and transforming scientific knowledge into the archaeological museum can be seen through the light of the above theoretical frame of mediating/museographic transposition. The key question, therefore, of how scientific knowledge can be introduced into an archaeological museum as an exhibition/communication element is: How interdisciplinary knowledge as described in section 3 is possible and feasible to be transformed into appropriate content, but mainly in a media device and setting for the user according to his cultural identity, his prior conceptions, his age and his cognitive and emotional needs (understanding, curiosity satisfaction, pleasure)? Our opinion is that the design and construction of an *original museographic structure* that will complement an existing archaeological mediating setting (original objects and their exhibition matrix) is the *necessary* condition that will allow the transformation of scientific knowledge into a media device. But, is it though *sufficient* condition as well, especially if the user belongs to a school group?

Both mediating transposition and museographic transposition have common roots to the *didactic transposition* which was first introduced to describe the adaptation of scientific knowledge to its teaching conditions in educational institutions such as schools (Arsac et al., 1994; Chevallard, 1991). Later, the term didactic transposition included other institutions such as science museums and centers (Triquet, 1993) and refers to the necessary reorganization of knowledge required by the act of teaching, disseminating and communicating or popularize. The question of reorganization knowledge can be considered from two points of view: a. of knowledge itself or b. of the one who learns. Didactic transposition proposes to distinguish scholarly knowledge from knowledge taught in the teaching institution - school or out-of-school. Didactic transposition of scientific knowledge is therefore a process that is related with communication and consequently concerned by the educational role of museums.

Furthermore, The educational role of museums is fulfilled through, inter alia, *educational programs*, that can lead to successful learning and emotional outcomes, especially if these programs are arising from the research cooperation between museum and formal education (school, university) (Allard, Boucher, & Forest, 1994; Koliopoulos, 2003; Meunier, 2018; Meunier & Luckerhoff, 2012; Publics et Musées, 1995; Koliopoulos & Gkouskou, 2020). Educational programs have the advantage to offer the public who follow a relatively high degree of interaction with the museography material and the relevant scientific knowledge. Based on the foregoing, we believe that designing a suitable museum structure with an *integral educational program* can be a complete, feasible and effective communicative/educational framework for disseminating scientific knowledge within the archaeological museum. In other words, it consists the necessary and *sufficient* condition of efficiency.

4.2 The dissemination of scientific knowledge in the archaeological museum: The Science Educative Islet

The *Science Educative Islet (SEI)* is a museographic structure comprising, on the one hand, original archaeological exhibits and on the other, a mobile unit with appropriate scientific equipment operating as an interdisciplinary educational microenvironment within the archaeological museum. This structure provides multisensory communicational tools as well as teaching processes that can lead students to construct elements of appropriate scientific knowledge. It may contribute to scientific culture formation and to the construction of critical thinking, with analysis and interpretation tools of a complex world, with tools of understanding the past and the present (Georgopoulou & Koliopoulos, 2017). It differs from specially designed multi-sensory rooms created in various forms since the mid-20th century in many science or art museums in that it is not separate from the main exhibition, but it is an integral part of it. Its purpose contributes to the familiarization of children with the main exhibition by providing scientific content and seamless eye contact with authentic ancient artifacts at the same time, using elements from the active learning methods and hands-on exhibits (Meunier, 2011). The concept of SEI combines, as mentioned above,

(a) the design of an appropriate *museum structure* to disseminate forms of interdisciplinary scientific knowledge associated with exhibits of an archaeological museum, and

(b) the design of a *related educational program* to support cognitive and emotional progress of the students who will attend the program.

We consider this structure as an original museum structure to be investigated. It proposes a different interpretative framework of the museum's archaeological collections and, at the same time, offers a supportive educational form so that the visitors could understand the purpose, intention and content of the exhibit.

The design of the SEI consists of three interconnected elements:

Scientific content narrative

This element concerns the transformation of scientific reference knowledge into content (as has been described in section 3) that will be communicated to the public of an archaeological museum through SEI (investigation of understanding the scientific content by at first: school pupils and then: other museum public groups). Defining the objectives of the transformation of this interdisciplinary scientific knowledge, its exact content (concepts, methods, cultural characteristics) and the specific narrative depend on (a) the scientific questions relating to the archaeological exhibits; (b) the nature and characteristics of the content of knowledge corresponding to each specific field of knowledge (see fig. 1) and (c) the cognitive and emotional profile of the target audience. The storytelling approach of science, namely the dissemination of scientific knowledge through narrative of stories, is suitable since it is a pleasant, interesting, and cognitively effective way of transforming some or all of the three components of reference scientific knowledge (Avraamidou & Osborne, 2009; Bruner, 2004; Klassen, 2009). For example, elements of scientific methodology (e.g. methodological steps can be followed by a scientist of archaeometry when studying the provenance of an archaeological object) could be the subject for a basic story of different cases of SEI. Such a narrative would also be compatible with the more general tendency to disseminate elements of the nature of science within formal education and/or non-formal education. At the same time, narrative elements related to specific cases of the history of science, technology or/and art could be added to this basic narrative.

The media device

Figure 2 shows the format of the mobile museographic structure of a SEI to be evaluated in situ at the Archaeological Museum of Thebes[14]. As one of the largest archaeological museums in Greece, it covers a historical range from prehistory to 1830, through its collections. The exhibition was designed to be accessible and cover the aspirations of a versatile public with diverse demands. The visitor has the opportunity to navigate through time in the centuries-old history of Boeotia by way of singular finds, digital applications, reconstructions, but also by way of the monuments themselves. The recent renewal of the exhibition, the thematic sections, the spaces and the archaeometric studies related with some of the exhibits conducted by the Fitch Laboratory of the British School at Athens are the main reasons for choosing this museum.

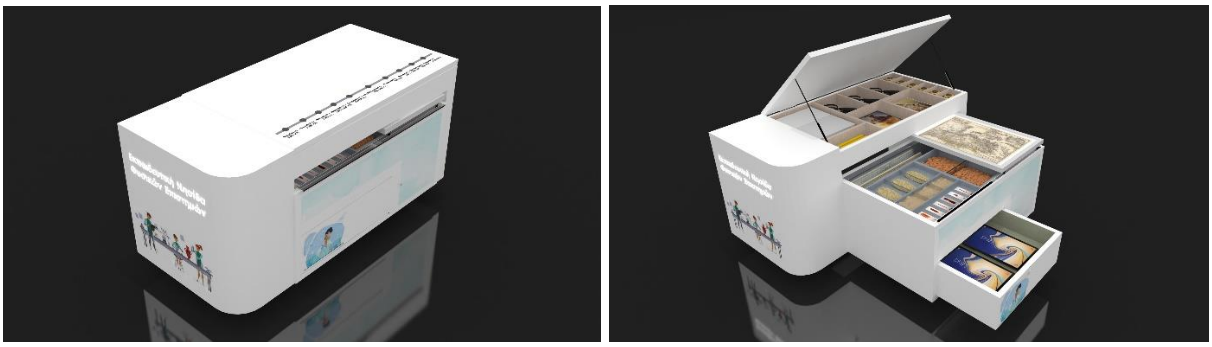

Figure 2: Format of the mobile museographic structure of a SEI. It opens gradually according to the educational program. Each level provides the methodological tools needed to examine scientific hypotheses.

The SEI consists of three parts look like as individual drawers for the educational material and it is combined with recesses where characteristic objects or tools are placed, corresponding to steps of a sequence of *scientific methodology* (e.g. tabs with scientific questions and/or working hypotheses relating with provenance of the original archaeological object-exhibit, instruments for collecting experimental data or different sources of information). These steps could be guide students' thinking to the next stage of a learning progression, which includes three methodological scientific stages: *a. formulation of research questions, b. formulation and testing of scientific hypotheses (i. at the macroscopic level and ii. at the microscopic level), c. formulation of conclusions.* In other words, they pass through hypothesis testing and data interpretation, to reach construction of scientific knowledge to answer the questions that have been asked.

This structure consists of the tangible part of the scientific part of the SEI and is connected with the original archaeological object-exhibit. The design takes into account not only the central exhibit but also the other exhibits of the room belonging to the same excavation or cultural context. It allows visual contact and facilitates interaction with the authenticity of the artifacts.

Figure 3: A Bronze-Age ceramic jar pithos, original archaeological object in the Archaeological Museum of Thebes, is appropriate for a SEI. The results of the archaeometric research conducted by the Fitch Laboratory of the British School at Athens were used to design a SEI and the educational program.

The media staging and the educational program

The order, the placement of tools, images, objects and scientific instruments is determined on one hand by the characteristics of the target group the SEI is addressed to and, on the other, by the nature of the educational program linked to museographic structure. The mediating object (e.g., the Bronze Age ceramic jar in Figure 3) is thus complemented by a proposal to design an appropriate space for the realization of the educational program. In Figure 4, an example of such a setting is shown to host a small group of primary school pupils to participate the educational program.

Figure 4: The formation of an educational environment around the museographic structure of a SEI. The mobile part of the museographic structure of a SEI surrounds the exhibit. It consists of three parts respectively of the three methodological scientific stages: a. formulation of research questions, b. examination of scientific hypotheses i. macroscopic way and ii. microscopic way, c. conclusions

The three elements mentioned above as components of the mediating transformation of scientific knowledge to be introduced as an interpretative approach to the exhibit(s) of an archaeological museum are closely linked. Guichard & Martinand (2000, p. 131) state that:

'These three inseparable components are understood together by the user of the media (a) according to his conceptions for the content, (b) his familiar practices, his age and his culture for the shaping of the object or of the subject, in particular for its aesthetic, interactive or playful components and (c) according to the emotional state induced and the conditioning of the user by the media staging ... '[Free translation by authors]

The media staging element is directly related to an educational program integrated in the SEI. The designing principals of the educational program will depend on a number of factors such as:

(a) the interpretative frameworks set by the museum. If, for example, the museum is particularly interested in trade networks or population mobility in ancient Greece, an interesting educational topic could be the provenance and local technology an artifact (Liritzis et al., 2020; Sarri, 2004; Xanthopoulou, Iliopoulos, & Liritzis, 2020) (b) the cultural, age or cognitive homogeneity of the group of people attending it. If, for example, the educational program is aimed at students of compulsory education (12-15 years), then the conceptual content of the curriculum should be compatible with the cognitive abilities and needs of these students. So, in the case of investigating the provenance of a ceramic material, students should be able to understand macroscopic and mesoscopic methods of observation and analysis of raw materials. In contrast, the involvement of microscopic methods of analysis or the use of atomic level symbolic language could create great cognitive difficulties in students of this age range (Besson & Viennot, 2004; Purzer, Krause, & Kelly, 2009) (c) the type of the program and the time required for its implementation. Educational programs offered in a museum environment can belong to various forms of informal, non-formal or formal-delocalized education (Meunier, 2018). The programs proposed by the museums themselves are usually short-term programs, while the programs designed in the context of museum-school cooperation require a longer implementation period of time. In both cases, it has been pointed out that the application of inquiry-based teaching approaches and hands on approaches can lead to effective learning (Gutwill & Allen, 2010). Our intention is that the above pedagogical characteristics be present in the educational program of the SEI.

Consequently, the design of a SEI, while seemingly structurally possible, presents a major difficulty in its design and implementation process related to many different parameters that must be taken into consideration to meet different needs of the SEI users. Giving priority to the design and evaluation in every step of its development of the educational program as the unifying component of a SEI may lead to overcoming this difficulty.

5. EPILOGUE

This paper aims to substantiate the view that scientific knowledge can be disseminated to visitors and especially to school groups in the archaeological museum setting, even if this is not the designated space to communicate natural sciences content. In summary, we have argued: (a) there is, at the social level, an international tendency among different types of museums to reach a range of audiences through the multi-interpretation and multidisciplinary approaches of their exhibits; (b) on the epistemological level, the emergence of interpretations of archaeological collections linked to the dissemination of knowledge of natural sciences and related social practices is possible; and (c) on the museographic level, it is feasible to design museographic structures and educational tools aimed at transforming scientific knowledge of archaeological museum collections into appropriate knowledge for visitors and especially school groups. The Science Educative Islet (SEI) combines for the first time the principles of didactic transformation of scientific knowledge and of exhibit-staging design. Designing, implementing and evaluating appropriate *case studies* of mediating transformed scientific knowledge within the archaeological museum, with the aim of investigating whether it is *feasible* for the visitors to construct elements of this knowledge, is the main focus of our research.

FOOTNOTES

[1]*http://ddschull.com/curatorial-trends-observations-on-inventing-abstraction1910-1925-and-impressionism-fashion-and-modernity/*
[2]*https://pinacotecabrera.org/en/proposte-educazione/transparent-restoration/*
[3]*https://www.vangoghmuseum.nl/en/explore-the-collection*
[4]*https://dma.org/art/conservation-dma*
[5]*https://www.dma.org/art/conservation-dma*
[6]*http://www.grandmuseeduparfum.fr/*
[7]*http://www.cite-sciences.fr/juniors/moyen-age/*
[8]*https://lugdunum.grandlyon.com/fr/Agenda/Tous-les-evenements/Evenements/1_Expositions/AQUA-L-invention-des-Romains*
[9]*https://www.theacropolismuseum.gr/en*
[10]*http://www.myrtis.gr/*
[11]*http://www.namuseum.gr/museum/pressreleases/2012/pressrelease_antikythera-gr.html*
[12]*https://pos.sissa.it/170/*
[13]*https://archive.artic.edu/sciarttech/*
[14]*https://www.mthv.gr/en/*

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