An interpretive and pedagogical approach of archaeological collections in the light of natural sciences: the notion of Science Educative Islet

POPI GEORGOPOULOU, KALLIOPI MELI, DIMITRIOS KOLIOPOULOS

Department of Educational Sciences
and Early Childhood Education
University of Patras
Greece
popigeorgopoulou@yahoo.com
kmeli@upatras.gr
dkoliop@upatras.gr

Abstract

It is rare to find, both in Greece and internationally, interpretive frameworks of archaeological museum collections or related educational activities that include elements of modern natural sciences. The field of archaeometry is perhaps the most appropriate interdisciplinary reference knowledge for such an interpretation of the archaeological museum collections. The Science Educative Islet (SEI), a museum structure mainly addressed to groups of children aged 11–13 years old, embodies the relationship between natural sciences and archaeology due to both museographic and didactic transposition simultaneously. This article (a) describes the design principles and the main characteristics of this museographic structure and (b) presents the results derived from investigating the conceptions of Greek archaeological museums' mediators. This investigation shows that most mediators are challenged when approaching topics that contain elements from the natural sciences. However, they emphasize not only the usefulness but also the need to introduce such elements in archaeological museum exhibitions and educational programs.

Keywords

Museology, science education, archaeological museum, interdisciplinary interpretation of museum collections, archaeometry

Résumé

Il est rare de trouver, tant en Grèce qu'à l'étranger, des dispositifs d'interprétation des collections de musées archéologiques ou encore des activités éducatives connexes qui incluent des éléments des sciences naturelles modernes. Le domaine de l'archéométrie est peut–être le savoir de référence interdisciplinaire le plus approprié pour une telle interprétation des collections des musées archéologiques. L'Îlot Éducatif Scientifique (IES), structure muséale destinée principalement à des groupes d'enfants âgés de 11 à 13 ans, incarne la relation entre les sciences naturelles et l'archéologie par une transposition à la fois muséographique et didactique. Cet article (a) décrit les principes de conception et les principales caractéristiques de cette structure muséographique et (b) présente les résultats issus d'une enquête sur les perceptions des médiateurs des musées archéologiques grecs. Cette enquête montre que la plupart des médiateurs sont pris au dépourvu lorsqu'ils abordent des sujets qui contiennent des notions de sciences naturelles. Ils soulignent, en outre, la pertinence (l'utilité et la nécessité) d'introduire de tels éléments au sein des expositions et des programmes éducatifs des musées archéologiques.

Mots–Clés

Muséologie, enseignement des sciences, musée archéologique, interprétation interdisciplinaire des collections muséales, archéométrie

Introduction: natural sciences in archeological museums?

The emerging trend in the museum field to find ways to remove thematic barriers and, at the same time, the growing interest in modern science's popularization is usually expressed by collaborations between museums of different types with each other. A typical example of interdisciplinary interpretive patterns is art exhibitions in science and technology museums or, vice versa, science lectures in art museums (Abadi, 2008; Blatchford & Blyth, 2019; Filippoupoliti, 2010).

However, limited systematic research concerns both (a) the epistemological analysis of the interdisciplinary knowledge to be disseminated resulting from these collaborations and (b) the investigation of the functionality of the museographic forms and the educational role they may incorporate. The lack of such research on the relationship between science and archaeological museum collections is almost complete, although one can find efforts to highlight this relationship mainly at the museographic level, in Greece and internationally (e.g., Cité des Sciences et de l'Industrie[1]; Musée

1 https://www.cite–sciences.fr/fr/ressources/expositions–passees/quoi–de–neuf–au–moyen–age

Gallo–romain, Lugdunum, Lyon[2]; Exhibition "Myrtis"[3]; Museum of Ancient Greek Technology, Athens[4]). Some of the questions that we can set in this direction concern the introduction of natural science elements as an interpretive framework for the archeological museum collections: (a) Is there an interdisciplinary relationship between archaeology and the natural sciences (*potentiality*)? (b) Is it possible to interpret the exhibits of an archeological museum in the light of natural sciences (*possibility*)? (c) Is it possible to disseminate natural science elements in the archaeological museum as an exhibit–communication element and/or as an educational tool? And more specifically, is it possible for this dissemination to take a museographic and didactic form in an archeological museum hall to address a student audience, which constitutes a large part of the archeological museum visitors anyway (*feasibility*)? And finally, (d) do the mediators of the museum's interpretive and pedagogical activities accept both the concept and the museographic/didactic product of this dissemination (*communication*)?

Our previous studies have highlighted social, epistemological, and museological arguments for documenting the possibility of introducing a modern version of scientific knowledge as a communication and educational tool in the archaeological museum (Georgopoulou, 2022; Georgopoulou & Koliopoulos 2017; Georgopoulou, Koliopoulos, & Meunier, 2021; Georgopoulou, Meunier, & Koliopoulos, 2020). In this paper, we focus on the last two questions of the previous paragraph. More specifically, (a) we describe the design principles and the basic features of a museographic structure, the *Science Educative Islet* (SEI), through which we claim that it is possible to implement the introduction of natural sciences in the form of archaeometry and methodology elements of science at the archaeological museum, and (b) we present the conceptions of Greek archaeological museum mediators regarding this museographic structure.

The notion of science educative islet

Design principles and main characteristics

The *SEI* is a museographic structure comprising original archaeological exhibits and a mobile unit with appropriate scientific equipment operating as an interdisciplinary educational microenvironment within the archaeological museum. It provides multisensory communicational tools and teaching processes to lead students toward constructing scientific knowledge. More specifically, the concept of SEI combines: (a) a specific *exhibit* or *group of exhibits* of an archaeological museum; (b) a *mobile museographic unit* related to the exhibit(s), designed to include the means of communication which contribute to

2 http://www.museegalloromain.grandlyon.com/
3 https://www.myrtis.gr/index.php?lang=en
4 http://kotsanas.com/gb/index.php

the dissemination of the desired interdisciplinary knowledge, (c) an *educational program* that is integrated into the first two SEI elements and aims to support the cognitive and emotional progress of students who will interact with the structure as a whole.

The basic design principles of a particular SEI entity are:

A. As for the exhibits, the design considers not only a central exhibit but also the other objects–findings of the exhibit subset (possibly from the same excavation) or other subsets of museum exhibits that belong to a common historical and cultural context (Hughes, 2010).

B. The spatial analysis elements that guided the design for the SEI mobile unit are the following:

(a) *Portability*. The mobile unit is not a permanent part of the exhibition. It is temporarily transferred and removed or stored as soon as the educational program ends, without permanently interfering with the exhibition. It avoids creating interpretive contradiction when the educational program is not in progress (Merriman, 2000).

(b) *Visual contact with the exhibit(s) in question*. Seamless visual contact with the showcases and the other findings of the excavation environment is required: The development of the educational condition of the islet within the exhibition space enhances the value of the archeological objects' authenticity and the public's multi–sensory engagement with them while allowing familiarity with the museum space and its functions, which is a constant goal for museum organizations (Beck & Cable, 2002; Chaitas & Kalou, 2007).

(c) *Compact structure*. The SEI mobile unit consists of a distinct material element with a specially designed interior to store all the communication means and educational tools in a suitable way that contributes to space and time saving (Merriman, 2000).

(d) *Correlation with the interdisciplinary knowledge to be disseminated*. The functional structure of the mobile unit should be directly and functionally related to the content of the scientific knowledge to be disseminated. On the other hand, the multiple interconnections between scientific knowledge and different types of archaeological exhibits force us to relate the structure to the methodological dimension of scientific knowledge rather than to the conceptual one to limit the possible versions of the mobile unit design. There is a potential correlation if the mobile unit design leads to an acceptable version of the physics and chemistry research methodology. These sciences are directly related to *Archaeometry*, which is the field that most strongly links these natural sciences to the archaeological exhibits of the museum (Georgopoulou et al., 2020). An acceptable research methodology in school science could be a hypothetico–deductive approach where the emphasis is on problem solving (in the case of SEI, archaeological problems that require archaeometry knowledge resources to be solved)

and on formulating and controlling scientific hypotheses through experimentation. Following this research methodology, the mobile structure may consist of parts that correspond to a specific methodological process, e.g., (i) formulating research questions, (ii) formulating and testing scientific hypotheses, and (iii) drawing conclusions.

(e) *Functionality and ergonomics:* The SEI mobile unit is designed to serve the movements of both the mediator and the visitors that participate in the training program (Neufert & Neufert, 2012; Tillman et al., 2018).

(f) *Usability:* The SEI mobile part is rather simple to avoid confusing users or diverting their interest from the cognitive content to the materials (Chaitas & Tsolaki, 2009; Merriman, 2000).

C. Regarding the training program, which is an integral part of SEI, we consider the following design principles:

(a) The *interpretive frameworks* set by the museum. If, for example, the museum is particularly interested in commercial networks or population mobility in ancient Greece, an interesting educational topic could be the origin and local technology of an artwork (Liritzis et al., 2020; Xanthopoulou, Iliopoulos, & Liritzis, 2020).

(b) In this case, the scientific knowledge *content* to be disseminated has an interdisciplinary character related to both the subject of archaeology and the modern knowledge of the natural sciences. Defining the objectives of this transposed interdisciplinary knowledge, the exact content (concepts, methods, and cultural characteristics), and the specific narrative (i.e., the way it is presented to the public) depend on: (i) the scientific questions related to the archaeological exhibits; (ii) the nature and characteristics of the knowledge content that corresponds to each particular knowledge field, and (iii) the cognitive and emotional profile of the target audience.

(c) The participants' cultural, age, and cognitive *homogeneity*. For example, if the curriculum addresses middle school students, then the curriculum's conceptual content must be compatible with these students' cognitive abilities and needs. Thus, in the case of investigating the origin of a ceramic material, students should be able to understand macroscopic and mesoscopic methods of observation and analysis of raw materials. On the contrary, microscopic analysis methods and the atomic–scale symbolic language could create extensive cognitive difficulties in students of this age range (Andersson, 1990; Besson & Viennot, 2004).

(d) The *type of educational setting* in which the program will take place and the *time* required for its implementation. It is important to note that a SEI educational program is not complementary but an integral part of SEI. Thus, the inside placement and arrangement of tools, images, objects, and scientific instruments internally is not random but comes as the result of a spatial study complying with the methodological process of archaeometry science. This condition corresponds to the non–formal educational setting that includes

all educational activities beyond the formal school system and can cause the participants' academic and cultural development (Koliopoulos & Meli, 2022; Meunier, 2018).

In conclusion, the SEI can be adapted to different exhibits of archaeological collections. These exhibits are linked to one or more scientific fields that allow the interaction between archaeological collections and natural sciences to serve the target audience's cognitive needs. The following section analyzes a SEI case study based on the concepts and methodology presented in this section.

A CASE STUDY AT THE ARCHAEOLOGICAL MUSEUM OF THEBES

The archeological exhibit

This case study concerns an exhibit of the Archaeological Museum of Thebes, one of the most significant archaeological museums in Greece, which covers a time range from prehistory to 1830 through its collections. The Middle Bronze Age "pithos" (jar) from Eutresis (Boeotia, Greece), which we selected as an archaeological reference exhibit, is a significant finding because it contributed to the understanding of the anthropogenic environment of central Greece during the Bronze Age (2nd millennium BC) (Aravantinos, 2010) and was, among other objects, subject for petrographic analysis and then for inductively coupled plasma–mass spectrometry (ICP–MS) test to determine the composition, technology, and, potentially, the origin of the ceramics (Hilditch et al., 2008) (Figure 1).

FIGURE 1

Archaeological Museum of Thebes, aspect of the Bronze Hall, the jar from Eutresis as a dominating exhibit surrounded by burial findings of the same period (photo by Popi Georgopoulou)

The mobile unit of the SEI's material part

Designing an element that is added in the exhibition context after its opening, one of the two options is followed: (a) the design follows the patterns, the color palette, the lines and the forms of the existing aesthetic perception of the exhibition, aiming at the aesthetic integration of the new element or (b) the design differs from the existing aesthetics, aiming at the visual distinction from the rest of the spatial approach, but also the conceptual approach. In the case of the design of this specific mobile unit, the second option was followed, which aimed at the distinct introduction in the space of the other exhibition. However, this does not mean that the opposite choice would be wrong. Each documented choice can meet different goals.

We designed the mobile unit of SEI[5] with three distinctive levels, following the methodological approach of the hypothetico–deductive schema of science. The introduction of *teaching activities–problems* is developed in the exhibition room dedicated to the Bronze Age excavation findings at the Archaeological Museum of Thebes (Figure 2). More specifically, the first level incorporated material related (a) to the emergence, identification, and formulation of one or more questions about the archaeological finding–exhibit's identity and origin and (b) to the hypothesis formulation and testing for solving the problem of specifying the object's particular characteristics (size, placement in time). These hypotheses require a macroscopic examination of the object, mainly based on *guided observation* with the help of the material provided at this developmental level (Figure 3). At the second level, students are presented with materials that help them formulate and test hypotheses for solving the problem of specifying the object's particular characteristics, using mainly mesoscopic observations (Figure 4). Finally, at the third level, the material presented helps students draw the final conclusions for the entire process, including the testing of the various hypotheses formulated to answer the initial questions (Figure 5).

Figure 2

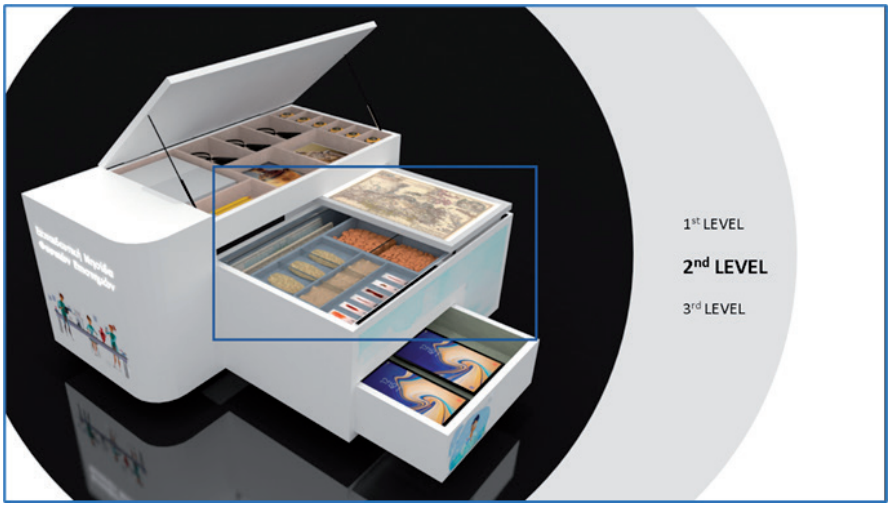
Photorealistic simulation of the educational environment configuration around the museographic structure of the SEI

5 https://www.youtube.com/watch?v=B3UTHabLdT8&t=1s

FIGURE 3

Photorealistic simulation of the SEI mobile unit's first level

FIGURE 4



Photorealistic simulation of the SEI mobile unit's second level

FIGURE 5

Photorealistic simulation of the SEI mobile unit's third level

We have already noted that a key feature of the SEI mobile unit is its flexibility. For the particular case of the SEI that belongs to the Archaeological Museum of Thebes, the archaeometry material can be adapted (e.g., by adding or changing archaeological maps) and/or be improved (e.g., by downloading quantitative data or better quality results with the use of a stereoscope) in the case of other ceramic objects.

The educational program

The target audience is students, particularly students 11–13 years old. In this case of ceramic jars, as the key element of the disseminated scientific knowledge, we choose the methodological dimension, that is, the methodological steps an archaeometry scientist follows in studying the archaeological object's origin. This choice is subjected to a narrative basis for disseminating elements referring to the nature of science, which increasingly concerns educational systems and science education research teams (McComas, 2020). On the other end, the conceptual dimension of archaeometry knowledge has been deliberately downgraded because it involves a complex conceptual system related to natural methods of material analysis (Liritzis et al., 2020). In this case, it concerns the petrographic analysis of ceramics and the experimental processing of geological samples from a wider area to study the local production of ceramic elements with oriental shapes. The didactic transposition of this reference knowledge into school knowledge for students of this age group seems to be, as we have already

pointed out, a tough and arduous task, especially due to the lack of systematic research addressing students' cognitive abilities in this field. Of course, the didactic objectives of the educational program are not limited to the methodological dimension of the interdisciplinary scientific (archaeometry) knowledge. The methodological goals comply with conceptual goals (physical and chemical properties of clay) and *cultural* goals (geographical distribution of clay objects in ancient Greece, modern archaeometry laboratory). Table 1 presents the three different types of objectives per teaching unit.

TABLE 1

Objectives of the educational program of the SEI for Archaeometry

Level of the SEI	Teaching unit	Activity - Problem	Conceptual objectives	Methodological objectives	Cultural objectives
1st	«Welcome - familiarization - introduction»	What might have been the use of a ceramic jar in antiquity?		The identification of the factors for the documentation of the object	Understanding the material culture of the past
1st	«Observation and conclusion»	What characteristics of a ceramic ancient jar compose its identity?	Shape description	Macroscopic description of a ceramic object (measurement of length, width, height)	The definition of use as a historical-archaeological problem
1st	«Placement in time»	How does the typology of pottery along with the timeline lead to the dating of an ancient jar?	Dating	Chronological sequence recognition	Dating as a historical-archaeological problem
2nd	«Finding the origin»	How does the combination of the clay composition of a ceramic with the list of clay soils of different positions lead to the determination of its origin?	Origin	- Mesoscopic analysis of the composition of the clay - Use of geological maps	- Geographical distribution of clay objects in ancient Greece - Origin as a historical-archaeological problem
3rd	«Summary and verification»	Is the recognition process successfully repeated?		- Drawing conclusions - Summarizing of methodological procedures	

More specifically, the educational program is structured in five modules with the following titles: (a) "Welcome – familiarization – introduction", (b) "I observe and conclude", (c) "I place in time", (d) "I find the origin", and (e) "I summarize and verify". In the beginning, the school team members get acquainted with the mediator and each other to build an atmosphere of intimacy and trust. Then, students are first asked to identify the usefulness of the jar by macroscopically examining the archaeological exhibit, using tools from the first level of the mobile unit ("Observe and Conclude" section – Figure 6). Also, the series of cards with corresponding jars from different historical eras, from prehistory to the present, allows them to classify the images and identify the archeological exhibit with the corresponding image from the Bronze Age, answering a question about the age of the object (Section "I place in time").

Figure 6

It is expected that students may not be able to answer the question about the origin of the archaeological exhibit, as the evidence from the macroscopic examination is insufficient. Thus, they move on to the mesoscopic examination using proper instruments, such as the microscope (Figures 7 and 8). In this respect, they utilize classified clay samples (powder, unbaked and baked pieces). Research shows that children aged 11 and over begin to understand better the concept of solid state of matter (Andersson, 1990; Driver et al., 2014). As the jar's origin depends on the origin of the clay, students are prompted to combine mesoscopic images of the petrographic analysis of clay jars that belong to the Archaeological Museum of Thebes collection with the geological maps of Attica and Boeotia. On the luminous surface of the SEI mobile unit, they can observe details of the clay composition that was used for specific constructions. Afterward, they can document the jar.

Figure 7

Figure 8

In the third and final part, students are asked to verify the scientific process elements they used by putting six phrases in the correct order so they summarize their actions up to that point. The corresponding numbers reveal a six–digit code, which unlocks the tablet and allows them to watch a video showing the inside of archaeometry laboratories[6].

6 https://youtu.be/ze8sPf9tUqA and https://youtu.be/4t–ZnFQr4wE.

Investigating mediators' conceptions about the science educative islet

The framework

To evaluate the SEI, we surveyed Greek museum mediators. The role of the mediator/museum educator is crucial for the effectiveness of any educational activity that takes place in the museum. The mediator is responsible for bringing in terms of museum collections' impact, the interpretive framework of the exhibition, and the respective audience group. Their awareness, cognitive competence, and attitude affect the museum visitor both directly and indirectly.

The general aim of the research under discussion was, on the one hand, to investigate their attitude toward utilizing and disseminating natural sciences in the context of an archaeological museum and, on the other hand, to evaluate the design of the SEI mobile unit, as well as the corresponding educational program. In this respect, only a few relevant studies are available, at least to our knowledge. One of them refers to the views that exhibition designers hold, specifically regarding collections in history museums in the United Kingdom (Copley, 2010). Copley explored the views of 100 archaeologists on the extent and characteristics that scientific content should have in the context of archeological exhibitions. The results of the survey designated a contradiction in the views of the respondents. On the one hand, most of them considered that the archeological museum was a suitable place for disseminating elements of natural sciences and that the inclusion of such elements in the exhibits would not bother the audience. However, only a few of them had designed relevant museographic material, and they also noted that the museum they worked at did not include such exhibits. An interesting aspect of this research was the scientific knowledge content that the mediators suggested could be disseminated through the exhibits/exhibitions. In order of preference, the mediators mentioned dating techniques, paleomedical data, stratigraphic data related to the excavations, and maintenance data. On the other end, they hardly mentioned archaeobiology, geophysics, and scientific method elements.

One of the authors of the current paper carried out another study regarding the scientists' views whose research interests concern archaeometry, archaeological material conservation, and ancient Greek science, technology and art (Georgopoulou, 2022). Overall, the data analysis showed that the experts' conceptions are fully compatible with the epistemological approach we suggest in the present article. More specifically, this analysis focused on how the experts viewed the conceptual, methodological, and cultural content of the required interdisciplinary knowledge in introducing natural sciences as an additional tool for interpreting the archaeological museums' collections. At the same time, the experts stressed the potential to disseminate this knowledge to the archaeological museum, that is, in a non–privileged cultural environment for the

communication of natural sciences. However, the experts did not express this potential clearly, which was rather expected since none had particular knowledge of science communication and/or education.

The research we present here explores people's views who can potentially *disseminate* the pertinent interdisciplinary knowledge in a museum setting. Therefore, it can be considered complementary to the research mentioned above on experts who *produce* this type of knowledge.

The participants

As shown in Table 2, the participants were individuals from different museums and cultural institutions and had a suitable combination of undergraduate and postgraduate studies. These were people who had systematically worked in educational museum settings. The combination of their undergraduate and postgraduate studies varied, thus creating a representative sample of professionals (not volunteers) who held respective positions in Greek museums or collaborated with them.

TABLE 2

Participants' profile

	Job title	Bachelor's degree studies	Masters' degree studies	PhD studies	Employment / position	Experience
1	Archaeologist Museologist	Archaeology	Maritime Archaeology	Maritime Museums and National Identity	1. Teaching staff at the Open Hellenic University 2. Maritime Museum of the Aegean Sea	>10
2	Elementary School Teacher	Primary Education	Science Education	Construction of students' knowledge, through conceptual mapping	Teaching staff at the University of Patras	>10
3	Cultural Management Consultant	- Conservation of Antiquities and Works of Art - Architectural Engineering	1. Museum Studies 2. Architecture	The museum as a means of communication	Cultural Management Consultant	<10

TABLE 2

	Job title	Bachelor's degree studies	Masters' degree studies	PhD studies	Employment / position	Experience
4	Museologist Museum Educator	European Studies (History of Art)	Museum Management	-	Designing museum exhibitions and educational programs (Telecommunications Museum, Municipal Gallery of Athens)	>10
5	Mathematician Cultural Project Manager	Department of Mathematics	Cultural Management	-	Mediator in museums exhibitions	<10
6	Archaeologist	Archaeology and History of Art	Cultural unit management	The Mycenaean ivory workshops in Boeotia, Greece	Archaeologist at the Ephorate of Antiquities in Boeotia, responsible for educational programs	>10
7	Museologist	Philosophy, Pedagogy and Psychology	Museum Studies	Cultural Diplomacy	Head of public programs at the Archaeological Museum of Patras, Greece	>10
8	Archaeologist Museum Educator	History and Archaeology	Cultural Management	-	Department of Museum Educators in "Cultural Center of the Hellenic World"	>10
9	Archaeologist Museologist	Archaeology and History of Art	Museum Studies	-	Head of Educational Programs - Museum of Cycladic Art, Greece	>10
10	Archaeologist Writer	History - Archaeology	-	-	Head of the Office of Educational Programs, Ephorate of Antiquities of Piraeus and Islands, Greece	>10

The interview protocol

We conducted the research in March 2021, through a video–conferencing platform (due to restrictions caused by the pandemic Covid–19). We used individual semi–structured interviews as a data collection technique (Cohen, Manion, & Morrison, 2007). We designed the interview to last 30 to 40 minutes.

The interview protocol consisted of 3 question sets (Table 3). Question set A concerned the participants' scientific training and professional profile outline. Question set B aimed to explore their conceptions of the interdisciplinary relationship between archaeology and natural sciences at the archaeological museum and the interpretation of archaeological collections in the light of natural sciences. Question set C aimed at the evaluation of SEI and the investigation of utilization potential. We divided this third and final part of the interview into two distinct sections. The first one concerned the museographic elements (functionality, aesthetics, content), while the second concerned the museum–pedagogical elements (content, suitability for audience).

TABLE 3

Objectives and sets of questions

	Objectives	Questions
A	Outline of scientific and professional profile	Job Title Title of bachelor's degree Studies Title of master's degree Studies Title of doctoral studies
		Objective of employment /position Years of professional experience
B	Exploring their conceptions on the interdisciplinary relationship between archaeology and natural sciences at the Archaeological Museum (interpretation of archaeological collections in the light of natural sciences)	B1. What is your opinion about the interdisciplinary interpretation of antiquities as exhibits in an archeological museum (necessary, useful, indifferent, unnecessary)? Give any examples of interdisciplinary interpretation cases of archaeological exhibits.
		B2. Is there an interaction between natural sciences and the archeological museum, and which one? Give any examples from your own professional field of good practices in Greek museums or elsewhere that you may know.
		B3. If so, how do you think the interpretation of the archaeological museum collections could be achieved: (a) on the museography level? (b) on the educational level?
C	The evaluation of the SEI and the investigation of its potential utilization	C1. Express your opinion about SEI from a museographic point of view (functionality, aesthetics, content). Which element(s) would you change and why? Do you find any advantages?
		C2. Express your opinion about SEI from a museo-pedagogical point of view (content, suitability for audience). Which element(s) would you change and why? Do you find any advantages?

The results

Question B.1.

The aim of this section of questions was to explore the participants' conceptions about the interpretation of archaeological collections in the light of modern science and the integration of the relationship between archaeology and science in the educational dimension of the museum. Very interesting conclusions emerge from the analysis of the answers. Most participants used adjectives such as "useful" or "necessary," as some quotations below show.

> M.2.: I think it is necessary. It is the modern trend in the approach of exhibits.
> M.6.: It is not just necessary; I would say it is integral. Although it does not always appear, you cannot distinguish it.
> M.8.: […] Necessary for sure! I mean, I cannot think of any other way to do this in archaeological museums. […] 100% interdisciplinarity is needed!
> M.9.: I would definitely say useful, but over the years, as museums open to all groups of audiences, it is also necessary.

Therefore, the positive intention, the recognition of value and usefulness, and the connection with the new trends are evident elements of the new socio–cultural data. At the same time, however, confusion between the concepts of interdisciplinarity and multidisciplinarity is noted. Fourez (1997) introduced the term interdisciplinarity, distinguishing it from multidisciplinarity. The first term refers to a situation or problem with an existing interdisciplinary approach through the convergence of more sciences, while the second concerns the parallel examination of a more general subject from many different and independent angles. The following passage highlights this vague conception.

> M.3.: […] Interdisciplinary, I understand that you approach the exhibit from different thematic references with different subjects. We talk about ancient social life related to an exhibit, but at the same time, we talk about its technology or the political context that existed at the time it was found, for example.

Question B.2.

The second question prompted the participants to identify and discuss examples of such an interdisciplinary relationship, especially in the archaeological museum. All participants responded positively. Four of them made a direct and clear reference to the "material," referring to the material dimension, as shown in the following quotations:

> M.1.: Yes, I think there are interactions. Especially concerning the material the objects are made of. There are connections to organic and inorganic chemistry, physics, and more.

M.2.: […] The first thought that comes to me, the most direct, in relation to the natural sciences, is something that museums, the material, very often highlight. About marble, about clay, this piece is self–evident for the natural sciences.
M.5.: Ceramic findings, for example. Technological knowledge related to chemistry and physics has been used to make these.
M.9.: […] We are definitely talking about chemistry, about the construction of objects or dating.

Indeed, the nature and characteristics of those materials, which the archeological objects are made of, emerge as the most appropriate field for negotiating interdisciplinary knowledge. Only one of the participants mentioned that, although this is an interesting approach, they never had the opportunity to practice such an interdisciplinary subject. However, gathering the examples cited by all participants, even with the confusion we described earlier between the terms interdisciplinarity and multidisciplinarity, there seems to be an understanding of interdisciplinary osmosis in many cases. In this respect, the following examples are indicative:

M.1.: Museum of Nautical Arts in Samos: The stages of construction of a traditional boat and the connection with mathematics and physics.
M.2.: Archaeological Museum of Heraklion, Crete: Approach from the point of view of natural sciences, about clay and creation of ceramic objects.
M.3.: Archaeometric analysis with physicochemical methods performed on eight Egyptian mummies of the British Museum. The exhibition referred to the technology used.
M.4.: In a recent exhibition at the National Archaeological Museum, there was a multi–sensory approach of smells with plant motifs from ancient jars.
M.5.: The mechanism of Antikythera in the National Archaeological Museum of Greece.
M.6.: There aren't any exhibitions of this type.
M.7.: A Roman sundial, in Patras and its connection with ancient philosophy.
M.8.: The exhibition on ancient Greek mathematics at the Foundation of the Hellenic World, and the traveling exhibition "Idea" about ancient Greek science and technology. Respectively, the exhibitions of the museum in Heraklion. Also, the exhibition in Dispilio, about the relationship between prehistoric settlements and the natural sciences.
M.9.: At the Museum of Cycladic Art and the reference to the environment.
M.10.: The collection of bronze statues at the Archaeological Museum of Piraeus and its connection to the chemistry of copper.

Question B.3.

The third and final question of this set aimed at the distinction between the museographic and educational dimensions of the museum, exploring participants' conceptions of the potential that these two levels could have. Overall, the participants had a positive attitude toward the potential of developing interpretations in the direction of the discussion. All participants agreed on the necessity, usefulness and potential of interdisciplinary interpretation of archaeological exhibits in the light of the natural sciences. However, two interviewees highlighted two reasons they considered essential for the lack or delayed appearance of this relationship in current exhibitions and educational activities. The first reason referred to the background of professionals in charge of designing and implementing educational programs and activities in archeological museums. Their expertise is in History and Archeology; however, they are not familiar with methods of archaeometry, conservation, etc. Thus, they feel uncomfortable dealing with such topics, even though they recognize their value and interest.

> M.10.: To tell the truth we did not approach such topics in the past because we did not consider ourselves capable of dealing with them. But now, with the help of expert scientists, conservators, we can more easily approach them and present them to the public […]. Archaeologists are not omniscient. The point is to have a good collaboration with scientists from other fields […]. We had the conservators next to us in the past, but we didn't go to the next step. Now, in the field of museology – museum pedagogy, but also in the field of archaeology in general, we cannot perceive the excavation or the exhibition without the contribution of the natural sciences.

Secondly, the practices, techniques, and methods belonging to the field of natural sciences do not always find a seamless application due to high costs. Therefore, they are often excluded from the studies of archaeological findings, making natural sciences even more unfamiliar. The following quotation denotes this practical factor:

> M.6.: […] Nowadays, technological and scientific tools and methods are very helpful. In the past, this was difficult. Now, we have very accurate data analysis […], they are faster and less expensive. I have seen in archaeological records from the 1970s, for example, "We called the local dentist to examine the teeth of the ancient skull". I mean, such practical difficulties existed. However, from the 20th century, the natural sciences that deal directly or indirectly with archaeology have advanced in recent years. Now, you can send material from an ancient skeleton and have answers not only about his age but also about the diseases he had. It is incredible. Or send material from ancient jars and find out what kind of food was stored in them […]. And in the past, there was the intention, there was the inquiry, but in practice, it could not be done. That is why, perhaps, this interdisciplinary relationship is not so

obvious in the exhibitions of the classical archeological museums. It exists, but it is not so obvious. Analysis results like these are not usually part of the exhibition context because in archaeological museums, the spotlight is on the result, on the object, not on the method. In a thematic museum, however, which would be for a specific art or technique, there is or should be an emphasis on the path to the result […]. How this kind of interpretation can be achieved in the archeological museum is something I am interested in. Modern technology gives us opportunities for digital media. We now have a way to make the exhibit less academic and more accessible […]. At the educational level, we [at the Archaeological Museum of Thebes] work a lot with museum equipment and educational programs, and we collaborate with formal education teachers. Ideas like the ones you introduce will help us to also collaborate with physics, chemistry, and mathematics teachers, who would barely choose an archaeological museum.

Question C.1.

The third question set concerned the evaluation of the case study, i.e., the SEI for archaeometry designed for the Archaeological Museum of Thebes. We intended to investigate the participants' views on the SEI design principles, particularly on its utility, suitability, usability, aesthetics, and curriculum content. Most participants welcomed the idea of SEI, expressing positive or even enthusiastic comments. Portability, functionality, and clarity of structure were the three elements they all embraced.

M.1.: To begin, I think I would not change anything. I found it a very original idea and I find it a feasible idea, which is an advantage […]. I find it very innovative. It has methodological design, functionality, and it is clear about the content objectives.
M.2.: I find it both functional – that it is portable – and aesthetically beautiful […]. Both motivation and inquiry–based learning are enhanced. I perceive portability as a big advantage. First of all, I find it very original. I do not think I would change anything. I like that it is there, along with the original objects and that the educational part is directly connected to the exhibit.
M.3.: It reminds me of the drawers and hands–on exhibits […]. Its design is very clear. And especially the three levels, they are like stairs, like creating a ladder. I like it very much. It has the element of interaction.
M.4.: Ah, very nice! Yes, an island of experimentation. I like the movement element that there is this pop–up under development. It's very nice. Very nice. Aesthetically I like it very much because it stands out from the rest of the exhibition, but only so much that it makes you notice it […]. I like that it is a pop–up and then it can be removed from the site. I like that it has a color code. Functionality… looks very simple; it is user–friendly.
M.5.: Initially, I believe that SEI, aesthetically and conceptually, actually fills a

museographic gap of the archaeological museum […]. The three levels serve a somewhat exploratory feeling […]. Basically, the way it opens is a surprise.

M.6.: My heart is pounding! Perfect! Well, I really liked what I read now. And aesthetically, I like it. Maps are always needed; a timeline is always one of the key elements […]. I liked it in many ways, both practically and visually. I like that it is neat, tidy. It refers to a laboratory, it already connects you to the subject, you feel a bit like a scientist.

M.7.: In my opinion, materiality, geology, clay samples, and the correlation with the geomorphology are advantages. I also find the microscope wonderful. The important thing is that it moves. I would like to note the importance of the pop–up element for the new generation living through the digital transformation. The combination of physical, tactile, and digital content that will lead to knowledge acquisition is important.

M.8.: This islet in the area is very suitable. The discovery is very interesting for the children. From the museography point of view, the central exhibit is emphasized, it is completed with the rest of the collection… no, I haven't anything negative to say or something that I think will not work. I find it very comprehensive. Portability is an extra advantage.

M.9.: What I see is very interesting! Perfect! Nice really. It is definitely an interesting topic […]. It is original.

M.10.: Very nice idea! First of all, I liked the choice of the archaeological object because it is a free object and not in a showcase. I liked the idea of the archeological object acting as an axis of educational activity.

However, two participants also expressed their concerns about the aesthetic part of the design. Although aesthetics is more of a personal criterion, the following comments were related to the coherence and connection of the SEI with the rest of the museum exhibition.

M.3.: […] Aesthetically I like it. Ok, I would not make it white, I would rather prefer another color.

M.5.: […] I think it has such a simple design… I do not know if I can evaluate it as good or bad. I wonder if this very simple image, when closed, might not help someone understand what it is […]. My hesitation concerns the aesthetics, because yes, it is modern, but I do not know if "minimal" is attractive to children.

Another element raised by one of the participants concerned the term "islet" as part of the SEI description; more specifically, he had concerns about conceptual appropriateness/accuracy.

M.3.: […] I disagree with the term 'islet'. From thew museography point of view, the

> educational island means that the visitor is educationally autonomous […]. I do not know if I would call it an "islet," but rather an "event." But with Fourez explaining the meaning, it makes sense.

Question C.2.

The last question of the final set concerned the museo–pedagogical dimension of the accompanying educational program. More specifically, the aim was to investigate the mediators' views on the content and the public target group. All participants seemed to understand the importance of determining the age level to which the educational program is addressed. Four of them particularly mentioned that the number of participants should be small, as suggested.

> M.2.: […] The children are in the age phase of solving problems, so nothing bothers me.
> M.4.: […] I find it very good for children, especially for this small group of six children. These are ages that work together and want to act.
> M.5.: […] And yes, I think it is suitable for children of this age level. For younger children, it would seem strange to me.
> M.8: There is no reason for me to be concerned, because I saw that it is for a small number of children, only six. A large number would trouble me. That alone would trouble me. Nothing else.

However, one participant, experienced as a mediator–archaeologist, took into account that these ages visit the museum mostly as students, and therefore in large groups, and was concerned that all students would not use the SEI at the same time.

> M.6.: […] I am a little worried about the limit on the number of participants. We usually welcome school classes. I would need parallel SEIs for each group, with different topics but the same methodology, to cover different sciences. But, due to the lack of staff, it is difficult to divide school groups into subgroups in different museum areas.

Regarding the comments on the content, the answers showed that the central theme, educational tools, and objectives were clear to the interviewees.

> M.1.: […] It is good that it approaches the object both macroscopically and microscopically. In the end, there are also the summary questions, the materials are connected to the exhibition, so the object is put in a framework.
> M.2.: I really like that they will consider that the macroscopic examination does not give them all the answers, and they will be asked to look for more systematic ways to get the answers finally. This is the educational element of cognitive conflict. You don't tell them, "I give you the tool", but they themselves will say, "oh, what I know

is not enough". I like it very much […]. I am not concerned about anything; the flow is very nice… to assume, to conclude, to draw further conclusions.

M.3.: […] I think it is very compact, that is what I like […]. I like it because it has step one, step two ... And that cultivates skills, such as teamwork, etc.

M.4.: Children are involved with the right tools. Because children are constantly tired of being the helpers of adults. They also want to have their own role, to consider something on their own. Here they are given the opportunity to be the ones who will examine it. The fact that there are as many tools as the kids is very good. Sometimes it is awkward for them to wait for their turn. Of course, at these ages, they also want to work together. Oh, and the existence of the microscope is very nice. Participants literally follow the process of archaeometry research in a very realistic environment, where they suddenly initiate the process of measuring, touching, observing through the microscope. I think it has what it takes to be a very successful educational program and very essential. It includes hands–on activities. You've got an a–z experience. So, I find it very nice.

M.5.: I like it very much, in general. This educational program seems very interesting to me. I understand that the material part of the islet is necessary. So I believe that the design of the islet responds very well to the way the educational program is structured. Certainly, through this program, it becomes clear why there are these three levels that we see on the islet […]. I do not think I have much to say as it seems complete to me. Surely it sparks children's imagination so they can feel like they are inside the laboratory. I see that the islet has a bit of a cubic shape, so you can imagine that, inside the square of an archaeological museum, you are literally somewhere else, in a hidden room or even deeper, and discover the path of a jar through natural sciences.

M.7.: It also combines materials, conservation, geography and the interdisciplinarity that lies behind the exhibit. This information is often a completely uncharted field for the visitor. The SEI includes this interdisciplinarity.

M.9: It is new, very new. I believe it includes the right things. It gives the children the opportunity to participate throughout, there is tangible material, participation with leaflets…, so it is also based on educational theories, the museum basics which are exploratory, collaborative… I mention (these basics) as indicative. Basically, it is based on the child and their active participation. And that the children draw their own conclusions on their own participation since everything is designed in the way that I saw now, so that the children participate, ask questions, answer questions and thus gain knowledge through their active participation.

M.10.: It is extremely interesting! It's interesting because it explains how a scientist can come to a conclusion […]. All these stages where children are asked to compose research results and come to conclusions are pedagogically excellent! That is, it is

> a very solid foundation for an educational program. It is very well structured, like what we say in creative writing, "with beginning, middle, end", because that is also important. Many times, when we design an educational program, we are excited about our topic, we want to say it all, we exaggerate a bit; to say one thing, to say another, but here I see a balance. The design is very harmonious. I think it is very original.

In addition, the presentation of the educational program's content highlighted the fact that mediators were uncomfortable handling interdisciplinary topics. Thus, it brought to light the overall need for the museum staff's training. Eventually, direct or indirect comments revealed that the participants comprehended the importance of their role as mediators.

> M.2.: […] The mediator's role is crucial. The mediator's personality will come out… and how they will do it.

Four participants proposed a universal use of the SEI in the museum exhibition context, in the form of a clarifying question or comment.

> M.1.: […] But it is also an exhibit in a museum. So, could he have a permanent presence in a museum?

Regarding the proposal for the SEI to be a permanent part of a museum exhibition, it is more due to the need to renew the interpretive framework of archaeological museums in a more interdisciplinary and interactive direction, addressing other public groups (e.g., younger or older students, foreigners, etc.).

> M.5.: I find the SEI useful for the museum itself. To create different narratives, different approaches around an exhibit because in this way it also attracts different target groups.
> M.10.: […] The SEI would not impress, however, just the children; it would definitely impress adults as well!

Epilogue

Science and Technology museums are natural places to communicate and disseminate natural sciences to the general public (Schiele, 2021). However, at the same time, the dissemination of science elements out of their context is a constantly expanding socio–cultural trend. This comes from a social need to upgrade the cultural role that the natural sciences are called upon to play in modern society (Lévy–Leblond, 2004). As a particular form of this trend, art and history museums modify their interpretive approaches toward interdisciplinary approaches to their collections. We designed the

SEI, which suggests an interdisciplinary interpretive model of archaeological museum collections, as a particular form of implementation in the context of this approach. The SEI can function as an islet–state within the rest of the museographic environment and consists of (a) the original archaeological reference exhibit, (b) its mobile unit containing specimens, tools, and instruments, and (c) the supplementary, yet integral, educational program.

To evaluate the SEI of the case study, we interviewed Greek museum mediators. An important research finding was a remarkable contradiction regarding the participants' attitude toward introducing natural science elements in the museum exhibitions and the educational programs of the archeological museums. Although they emphasized that these elements would be not only useful but also necessary, at the same time, they seemed uncomfortable approaching topics that include such elements. Trying to explain the latter, we can draw our attention to (a) the typically limited scientific capacity of the archeological museum managers/curators in Greece and (b) the traditionally limited application of natural science methods to answer archaeological questions about dating and origin. The answer analysis included in the present research revealed striking similarities with the British archaeologists' views on their discomfort regarding the introduction of natural sciences in the Archaeological Museum (Copley, 2010). In addition, it appears from the responses of the research participants that it is not only possible but also desirable, with the necessary adjustments, to expand the application and use of a SEI. An important feature of the concept of SEI is its flexibility, i.e., the ability to adapt to different age levels and updated data of interdisciplinary reference knowledge.

We suggest that the development, implementation, and evaluation of such innovative methods, like the one described in this paper, promote the operation and role of archaeological museums, as institutional structures, in the direction of expanding their interpretive tools and optimizing their access services to the cognitive stock of tangible and intangible cultural heritage. At the same time, the natural sciences acquire a new, almost inaccessible until now, cultural space for their dissemination, expanding the boundaries of their communication with the citizens and especially with the student populations and thus strengthening the audience's weak correlation with culture (Bensaude–Vincent 2001; Lévy–Leblond, 2004). Also, educational research is certainly enriched with new elements. In this case, this research is conducted within a common area that is formed between the research fields of Science Education and Museology of Natural Sciences (Guichard & Martinand, 2000; Filippoupoliti & Koliopoulos, 2014; Koliopoulos, 2017). Implementing the proposed educational program and investigating the possible cognitive and emotional progress of children groups to whom the SEI design is addressed (11–13 years old) is in progress.

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