

Worth a Thousand Words? The Usefulness of Immersive Virtual Reality for Learning in Cultural Heritage Settings

Laia Pujol Tost and Maria Economou

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The goal of this paper is to investigate whether immersive virtual reality is suitable for learning about archaeology and the past in cultural heritage settings. To that end it presents the conclusions related to learning from the visitors' survey undertaken in 2007 by the Museology Laboratory of the University of the Aegean at the Hellenic Cosmos (the exhibition centre of the Foundation of the Hellenic World) in Athens, and contrasts these with other similar studies. This project was aimed at comparing the learning outcomes, perception and use by audiences of two different virtual reality systems and a related exhibition. It included qualitative and quantitative analysis of the data gathered through in situ observations, interviews with museum educators and face-to-face questionnaires with visitors. The results confirmed that, as previous studies have shown, virtual reality systems allow a different kind of learning, but also questioned the common belief about their advantage for children in comparison with other interpretation methods.

I. INTRODUCTION

The introduction of virtual reality (VR) in the cultural heritage field as both a communication and a learning tool over the last decade has attracted considerable interest from researchers and cultural heritage practitioners in evaluating its effectiveness in both directions. Audiences and professionals within the sector – archaeologists, cultural mediators, specialists in information and communication technologies (ICT) – commonly believe that VR is especially suitable for children and for informal learning environments, such as cultural heritage settings. This belief is based on some VR features shared with traditional means of museum communication and on the extrapolation of previous results obtained in formal learning environments with regard to the most suitable subjects, cognitive gains and learning processes when using these applications.

However, research has shown that virtual learning environments (or VLE, as pedagogical computer applications are called in the formal learning environment) cannot be considered in the same way as usual museographical resources because even when transferred to an exhibition, their design as exhibits is determined by their computational interface [20]. Similarly, informal learning environments, such as exhibitions, are different from formal learning environments with regard to the goals, availability of users' time for exploring the resources, or the role of social interaction. Therefore, there is a need to evaluate in situ the effectiveness of ICT applications for learning in cultural heritage settings, taking into account the specific goals and characteristics of these contexts.

The goal of this paper is to investigate whether immersive VR is suitable for learning about archaeology and the past in cultural heritage settings. To that end it will present the results related to learning from the visitors' survey undertaken in 2007 by the Museology Laboratory of the University of the Aegean at the Hellenic Cosmos, the cultural centre of the Foundation of the Hellenic World in Athens, and compare these with previous studies in order to reach some conclusions about the potential usefulness of VR as a learning tool for cultural heritage.

2. THE USEFULNESS OF VR FOR LEARNING IN CULTURAL HERITAGE SETTINGS

In spite of the high cost of VR devices, museums have been introducing them within their usual repertoire of communication tools for three main reasons [18]: commercial pressures; the capacity to transcend the physical space of the exhibition with their potential for virtual reconstructions; and their ability to support the educational role of the museum. Only few studies have exclusively focused on ICT's effectiveness for learning in cultural heritage settings. Until now this aspect was more often included within wider visitor surveys or was extrapolated from the formal learning environments, where the effectiveness of VLE has been systematically

studied. The related literature (see [4] for a critical review) shows that, especially in the later contexts, technological applications have positive results with regard to impact, iconic skills and improvement of engagement. However, in the case of exhibitions, some negative aspects have also been evidenced, such as problems of integration with the rest of exhibits, obstruction of learning by non-intuitive interfaces, and limitation of social interaction due to the one-to-one communication paradigm of these applications.

One of the oldest specific examples in the cultural heritage field is a study [12] at the Computer Museum in Boston aimed at evaluating the potential of VR for education and emotional satisfaction in a simulation of the real world. The observations inside the room showed that people spontaneously preferred to learn through the interactive experience instead of reading text, which was systematically marginalised. The main problem in that application was to get familiar with the interface: visitors spent between 5–10 minutes to understand the rules and aims of the simulation.

The survey conducted at the temporary exhibition “Immaginare Roma Antica”, held in Rome in 2005 [5], analyzed the perception and use of different kinds of ICT exhibits. The factors attributed by visitors to the suitability for learning were: richness of information (in the case of multimedia); quality of reconstruction (in the case of VR applications); and in all cases, link with previous knowledge. Nevertheless, observations showed that these factors would have no effect on learning if the interface and the organization of the content were not intuitive.

A study analyzing the effects of immersion in several science museums used a typology based on the kind of representation and the knowledge domain [1]. The results showed that immersive devices do not guarantee an immediate acquisition of knowledge or positive attitude towards the experience (with the exception of younger users) and that the operation needs to be as multi-sensorial and natural as possible, because otherwise the understanding of the content is compromised.

Finally, the contribution of computational interactivity was analyzed through an in-depth evaluation at the Enam Archaeological Museum in Belgium in 2006 [16]. According to visitors’ opinion, technology is appropriate for learning because it allows a flexible, personalized exploration of a richer quantity of information. In the case of VR, it offers the possibility to reconstruct and manipulate elements (buildings, objects) or phenomena (historical processes) which cannot be seen anymore. Nevertheless, researchers also understood that in the last case, images need to be supported by a verbal discourse because since they tend to be photorealistic, they cannot represent abstract elements such as external causal agents, social relationships, etc., where more schematic representations and especially verbal language excel. Nevertheless, observations evidenced again that there can only be understanding or learning when all problems related with the interface design are previously solved.

The conclusion from these studies is that VR is attractive and motivational, especially for younger visitors, and perceived as a useful tool for learning descriptive content about objects and processes. Nevertheless, learning or understanding will only be achieved if the physical and virtual interfaces are multisensorial and intuitive enough.

3. EVALUATION AT THE HELLENIC COSMOS, FOUNDATION OF THE HELLENIC WORLD

3.1. The Hellenic Cosmos

The Foundation of the Hellenic World [6] is a Greek privately funded non-profit cultural heritage institution based in Athens, Greece. It aims at the preservation and dissemination of Hellenic history and culture in order to create an awareness of the universal dimension of Hellenism and its active contribution to cultural evolution. VR technology is used in two ways at the Foundation: as a tool for research and as a tool to disseminate this knowledge. The latter is mainly done through the Hellenic Cosmos (figure 1), a cultural centre founded in 1998 and based in a former industrial area of Athens now in transformation, which uses state-of-the-art ICT and museological trends to offer educational programmes, virtual reconstructions, documentaries and exhibitions.

► Figure 1. The Hellenic Cosmos in Athens.



At the time the survey took place, the Hellenic Cosmos had three main exhibits involving ICT on display. Kivotos, inaugurated in 1999, is the oldest system. It is a CAVE-like system composed by 4 back-projection screens delimiting an area of 3m³, where a group of maximum 10 people is immersed in different shows, mainly reconstructions of archaeological sites, such as Olympia or the ancient city of Miletus. Users wear stereoscopic glasses, which create a real 3D effect. The interaction with the system is controlled by the museum educator, who moves within the virtual world with the help of a wand and a tracking system on her head.

Tholos, the newest system, inaugurated in December 2006, is a virtual reality theatre made of a semi-spherical screen inclined 23° and surrounding

a room with 132 seats, each one equipped with a joystick and four buttons. The evaluated application, the first one designed for this system, presents a reconstruction of the ancient agora of Athens in three different periods. The interaction with the system takes again the form of a spatial navigation and is led by a first museum educator with the help of a wand, while a second guide provides the archaeological content (description of the buildings' functions). Finally, the exhibition, complementing Tholos' content, presents information about the evolution of the agora, its historical meaning and institutions, and how these have been transmitted until today. It combines different types of exhibits (text, images, hands-on and technological applications), which allow different kinds of exploration and degrees of collaborative interaction.

The unique concentration of VR systems and high-tech exhibits, combining different degrees of interactivity, immersivity and social interaction, made this cultural centre very suitable as a case study for our research investigating the suitability of ICT for cultural heritage settings and its perception and use by audiences. At the same time, it allowed us to refine our methodology specifically designed for the evaluation of technological exhibits in museums, which takes into account and ultimately integrates all the factors involved in their use: the interface features, the visitors' characteristics and the context (spatial configuration and social interactions).

3.2. Goals and Methodology

The visitor survey conducted at the Hellenic Cosmos of the Foundation of the Hellenic World had two specific goals. The first was to investigate the added value of Presence (see [19] for a comprehensive definition of the term) in the cultural heritage field. The second goal of the survey had to do with the suitability of high-tech exhibits for learning in cultural heritage museums. Given the results presented in the previous section, we were interested in analysing visitors' preferences about communication solutions for learning, and also tried to understand (using short-term recall and in-situ observations) what remained in their mind from these diverse experiences.

To meet these goals we used different methods (interviews with visitors, with staff and in situ observation) in order to record different kinds of information. By combining the advantages of qualitative methods (interpretation of answers and behaviours) and quantitative methods (statistical analysis of the previous) we expected to gain a better understanding of the subject by obtaining new knowledge and establishing relationships and explanative hypotheses. With regard to observation, the pilot tests demonstrated that, due to the specific settings, observation inside Tholos and Kivotos provided very poor or already known results. Consequently, we decided to concentrate it on the exhibition, where a standardized sheet with a floor plan and behaviour codes were used in order to record visitors' timings at each exhibit, paths and behaviours. These

data would allow a comparative analysis of the use of high- and low-tech, interactive and “traditional” exhibits in order to detect and understand preferences and social uses.

The role and opinion of museum educators played an important role in this research project, since they are the main navigators of the VR applications and mediators in the construction of meanings at the Hellenic Cosmos. Therefore, we conducted semi-structured recorded interviews with the guides, who told us about the usefulness of high- and low-tech exhibits; the role of guides; and visitors’ reactions and behaviours. However, the most important source of information were the semi-structured interviews with visitors. The questionnaires, both in Greek and in English, combined open-ended, likert and categorized questions, distributed in the following five sections: general questions about the Hellenic Cosmos (most liked and disliked exhibits); comparative questions about the feeling of Presence; preferences in communication solutions for learning (usefulness of the exhibits, suitability for learning, best way to convey information, content recall); quick cross questions about the exhibition; and finally, demographic data.

After pilot testing of the questionnaire and observation sheet in spring 2007, interviews with visitors were conducted for 15 days in July 2007. The survey was carried out by 4 interviewers, who collected a total amount of 97 interviews, 75 in Greek with Greek visitors and 22 in English, mainly with tourists. Interviews lasted between 15 and 30 minutes. After the data gathering, we carried out a qualitative as well as statistical analysis (categorization of open-ended answers, univariate and bivariate techniques), the results of which are partially presented below.

3.3. Results

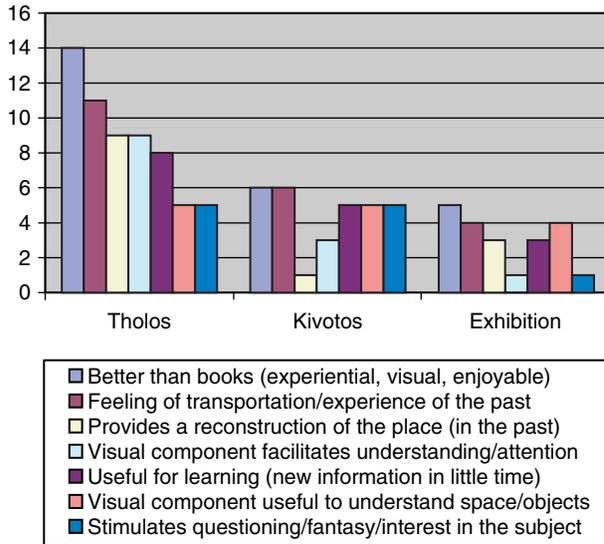
The third part of the questionnaire was devoted to learning. The first question (table 1) asked about the usefulness of the VR applications they had seen. As all VR exhibits were included in this overall count, the answers provide a general idea about visitors’ perception of the Hellenic Cosmos: it allows learning about places in the past thanks to the visual and experiential component of its exhibits.

► **Table 1. Usefulness of seen exhibitions.**

Usefulness of seen applications	Freq.	%
Better than books because experiential/enjoyable/visual/strongest impact	17	12, 9
Feeling of transportation/participation/experience of the past (life, buildings)	12	9, 1
Useful for learning (provides new information in a little time and nice way)	12	9, 1
Provides a reconstruction/image of buildings/the place (in the past)	10	7, 6
Visual component facilitates understanding/fixation/attention/accessibility	10	7, 6

With regard to the specific contribution of each exhibit (figure 2), we found out that Tholos was mainly appreciated by its experiential character. In the case of Kivotos, the “feeling of transportation/ participation

/experience of the past (people, life, buildings)” was the main contribution. With regard to the exhibition, its technological displays were also considered better than books thanks to their experiential and participative component. This question evidences the importance of the experiential component for learning (in comparison to books), which can be therefore considered the main characteristic of the Hellenic Cosmos as an informal learning environment.



◀ Figure 2. Specific contribution of each exhibit.

Once we had obtained a general idea of how visitors perceived VR applications, we wanted to understand how they related them with an exhibition. The Hellenic Cosmos provides a good example because Tholos and the exhibition present the same subject and Kivotos’ archaeological reconstructions can be considered quite similar to the 3D reconstruction of the “Ancient Agora”. In case the interviewees had not visited the exhibition, we asked them to imagine an exhibition with this subject and we took it into account in the contingency table. Both categories of visitors answered that VR exhibits provided an introduction, a general image about spatial aspects; while the exhibition, because it contained text, photographs and objects, provided more or more “substantial” (meaning factual or historical) information. This difference in the learning outcomes was independently confirmed, as we will see later, thanks to the question about content recall.

Given these results, we asked visitors which was the most suitable exhibit for learning about ancient Greece (table 2). Tholos and the exhibition were the most frequently mentioned, but taking into account the relative number of interviewed visitors in each one (86 for Tholos and 23 for the exhibition), it is evident that the exhibition was considered by far the most suitable exhibit for learning. This is confirmed by the general

questions about the Hellenic Cosmos. In this case, learning was selected by visitors as the second most important reason for choosing the exhibition as the most liked exhibit, but it was marginal for the VR systems. The reasons given were that that the exhibition provided “more detailed / well documented knowledge/explanations” and especially “new / more information about people / history / democracy” (10/19); that it was “richer in communication means” (4/19); and that it allowed visitors to “have control over their visit (time, activities)” (4/19).

► **Table 2. Best exhibit for learning about ancient Greece.**

Exhibit	Freq.	%
None	1	1,9
Tholos	19	35,2
Kivotos	5	9,3
Exhibition	19	35,2
All	2	3,7
Tholos + Kivotos	4	7,4
Tholos + Exhibition	4	7,4
Total	54	100
System	61	
Total	115	

These results do not exclude the usefulness of the technological exhibits, which were more suitable to “perceive/describe the remains/place/spatial details” (4/18 for Tholos and 4/5 for Kivotos). More specifically, according to visitors, Tholos had the advantage that it “combines images and oral explanations” (3/18) and therefore “provides a good general idea within limited time and place”, which made it “good or easier for wide audience” and especially for children. The other VR system, Kivotos, was also considered “useful to perceive/describe the remains/place/spatial details” (4/5), but in this case, its main advantages were the possibility to establish a closer relationship with the exhibit and the guide, as well as to play a more active role (2/5).

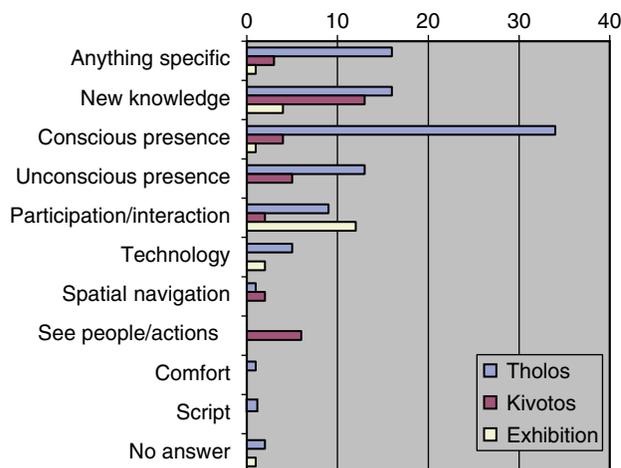
► **Table 3. Communicational preferences for learning.**

Communicational preferences	Freq.	%
Human guide	74	68,5
Audio commentary	11	10,2
Audio-guide	11	10,2
Images alone	8	7,4
Text	4	3,7
Total	108	100

The next question was related to visitors’ preferences in communication solutions for learning (table 3). Visitors considered that the best way to explore the application at both VR applications was with a human guide, because this allows a direct interpersonal interaction, thanks to which

he/she immediately adapts to the audience and can solve doubts or provide more information (20/63). Another reason was that some visitors do not like machines and think that “a human is more immediate/alive/spontaneous/non-standardized” (20/63). The exception to this were children, who although recognizing that guides can solve doubts and give more information, still preferred to explore the virtual world alone because they like technology. With regard to the rest of visitors’ preferences, we found out that audio-guides were preferred because they “allow choosing language/level of information/control over your visit” (3/4) or by those who “did not like the guide (explanation/articulation/attitude)” (2/7). Those who wanted the audio commentary (4/7) had had problems with the guide (“voice/navigation style disrupts the feeling of being there”). Text was chosen because it was considered “better for learning” (2/3) and could be taken away (1/3). Finally, images alone were chosen because of individual skills and preferences, by people who “prefer (simple instructions and) individual exploration” (3/3).

Through visitors’ answers in this section of the questionnaire and in the general questions about the Hellenic Cosmos, we found out that the different exhibits (technological vs exhibition) were probably allowing different kinds of learning. By analyzing which specific content visitors remembered from their experience at the different exhibits, either something they did not know before or something that impressed them, we could verify if this was true. In this way we could detect some aspects of cognitive gain (recall), while at the same time covering personal differences in learning/communication abilities, and taking into account the fact that, as it has been previously demonstrated [10;17], learning at VR displays cannot be measured through traditional text-based tests because it activates different mental skills. Therefore, we separated the answers by exhibit and we established two different variables: one gathering the detailed answers (with as many categories as answers in each exhibit) and one with 11 categories,



◀ Figure 3. Recall by exhibits (categorized).

valid for all exhibits and aimed at comparing the different kinds of output arising from each one (figure 3).

The most remembered aspect of Tholos' content was the transition from Classic to Hellenistic times, represented by the building of the Stoa of Attalus. We classified this as conscious Presence (34.7%) because, from our own experience, this part of the VR show exerted a very strong impact on our attention due to its combination of powerful (by size and volume) and dynamic audiovisual stimuli. Visitors felt unconscious Presence (13.3%, the third most frequent answer) when travelling through the amphora (10 cases), and at some points where they physically felt they were falling or flying (2 cases). We believe it was stronger at the amphora because the visual field was mainly occupied by one very big element (the ancient vase), moving very quickly, while the sensation of flying involves more visual elements and depends on the guide (smoothness of navigation and coincidence in the point of view). It is worth pointing out that unconscious Presence appeared in all age categories because it is an automatic reaction of the human brain, aimed at protecting the person, but conscious Presence was comparatively more frequent in younger ages (7–17 year-olds), which is probably related with children's natural capacity to suspend disbelief.

The second most frequent answer was "everything/anything specific" (16.3%). However, another 16.3% of answers reflected there was acquisition of new knowledge, related to elements that were very familiar to visitors and therefore acted as cognitive connectors. It is interesting to note that it was more difficult for children to say anything specific and to judge they had acquired new knowledge, which means that age is another factor intervening in recording learning outputs. And also gender: a striking 26.41% of women against 6.67% of men gave answers related to knowledge. Finally, in 9.2% of cases, visitors remembered participating (mainly at the ostracism part of the application) and 5.1% were also impressed by the size of the screen (technology).

Despite the fact that in the general questions Kivotos was not associated with learning, we found here that the most remembered thing had to do with the acquisition of new knowledge (37.1%), especially in those above 17 years and in female visitors (66.6% against 36.84% of men). From the interviewees' answers we understood that this was due to the relevance of one of the subjects shown at the Kivotos: the Olympic Games are part of the Greek educational curriculum and of western European identity and therefore are well known, but have many differences with the modern games. The second most frequent answer, found across both genders and across all categories of age, was the presence of people performing activities in the virtual applications (17.1%).

The next most frequent answers had to do with Presence but the order was inversed with respect to Tholos. At Kivotos, there were more occurrences of unconscious (14.3%) than of conscious Presence (11.4%) appearing in all categories of age. In the first case, it was indicated by the

reflex movement of Kivotos' participants to avoid the javelin (2 cases), and the corporal sensation of flying (2 cases) and of passing through the objects (1). We believe that the relevant factors here were the true tri-dimensionality provided by the flickering glasses; the higher immersivity of the CAVE-like system (floor screen and isolation from the real world); and the proximity with the guide (bigger coincidence in the point of view). There were also moments of conscious Presence, when entering the stadium at Olympia (2) and when travelling with the boat (1) or diving at Miletus (1), another of the Kivotos' applications on the ancient Greek city in Asia Minor. Here again, acted a combination of dynamic immersive audiovisual stimuli (the noises of the stadium or the sea, the boat's perspective, the immersion inside the tunnel), which demonstrates the importance of capturing the user's attention with strong stimuli that isolate him/her from the real environment.

In the case of the exhibition, peoples' main recollection, across all interviewed ages, origins and genders, was not related to the acquisition of new knowledge (it was the second, with 19% of appearances) but with the possibility of participation/interaction (57.1%). This is due to the museographic design of the exhibition, which contained multiple interactive exhibits: visitors considered that the exhibition provided new knowledge about the historical dimension of the agora, but were impressed by the multiple hands-on exhibits (9 cases), the big touch screens (4 cases) and the VR multi-user exhibit (2 cases). This answer is confirmed by the specific questions about the exhibition, where interviewees who had visited it answered that the best exhibits for learning were the hands-on displays (29.2%), the VR multi-user application (20.8%), and the big touch screens (16.7%), whose virtual schematic/geographic representation, as people emphasized, allowed them to better understand a subject they had been taught at school.

A second reason for the second position of "new knowledge" in visitors' recalls is that due to the structure of the exhibition (made of different units easily identifiable), it was easier for them to mention the exhibit instead of the content: as a result, contents and museographic elements are mixed in our results. An element which would demonstrate this hypothesis is that, unlike Tholos, at the exhibition only 1 person was unable to mention something specific she had learned. On the other hand, it is interesting to note that here again tourists learnt more than Greeks, and that female visitors (33.3%) gave more answers related to knowledge than male ones (13.5%).

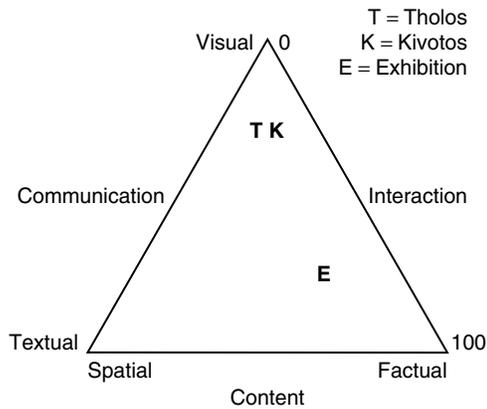
3.4. Discussion

One of the main goals of this survey was to investigate audiences' perception of ICT, and particularly of VR applications. As we had seen in previous evaluations [5,16] apart from an eventual interest in technology,

directly linked with the visitors' professional field (e.g. computing, architecture, etc), ICT are mainly understood as a tool for learning about cultural heritage. Nevertheless, subsequent results about the perceived or recorded learning benefits showed that there is a contradiction between users' demands from ICT to support learning and their real use or effectiveness. In the first case, when justifying their choice of the most liked exhibit, visitors mentioned knowledge or learning in the second position for the exhibition but in a marginal position (after reasons related mainly to technology and communication) for VR systems. Moreover, in the specific questions about general usefulness, specific contribution and suitability for learning, visitors underlined VR's experiential character and capacity to provide a general visual image, while the exhibition, although being also very interactive and experiential, was associated more with new, more detailed and well documented knowledge about historical facts, institutions and people.

The question about recall confirms that different exhibits provide different kinds of learning (more spatial, visual and superficial in the VR applications vs more factual, abstract and specific in the exhibition) and that people are more able to remember cultural contents in Kivotos and the exhibition than in Tholos. This would justify the apparent "conflict" between the known traditional way of learning (associated to text and exhibitions) and the experiential character of new media, which obviously transmit knowledge but probably do so in a different way than the one visitors expect or are able to perceive.

It is possible that because of the specific conditions of the Hellenic Cosmos' exhibits (but is probably extendable to all ICT applications in the cultural heritage field), interviewed visitors mixed different factors, and their answers with regard to the real suitability of ICT for cultural heritage settings are blurred. Visitors considered that the most suitable exhibit for learning was the exhibition because it combined different means of presentation (with an important presence of images and text), which could be explored freely in order to obtain factual or historical information. On the other hand, the technological exhibits, because of their audiovisual character, were considered suitable for obtaining spatial information. Yet, the difference in the effectiveness of the VR exhibits and the exhibition is more complicated than just the dichotomy visual/textual (figure 4). It involves content (spatial vs. historical), means of communication (audiovisual/experiential vs. textual) and also control and interaction (almost non-existent at the VR exhibits). And, more importantly, these factors are different and independent of each other, although there is a link of suitability between the first two: textual means seem to be more suitable for conveying historical information, while visual means are more efficient at showing spatial and dynamic information [4].



◀ Figure 4. Factors influencing the suitability of Hellenic Cosmos' exhibits for learning.

Therefore, as the case of Kivotos demonstrates, the use of visual information does not necessarily imply that the learning related to it is more superficial. It is also a matter of content. The constructivist learning paradigm states that previous knowledge is paramount for learning because it determines the relevance of the new information, acts as a “previous organizer” for its caption and generates the “cognitive conflict” that allows conceptual change [13]. This is what might have happened at Kivotos, which despite being visual, displayed a known subject (the Olympic Games), which was also relevant (showed human activity and was connected to visitors’ experiences) but presented differences with previous knowledge (between ancient and modern Olympic Games).

On the other hand, visitors’ apparent incapacity to say anything specific they had learned at Tholos may also be due to a methodological issue related to the representation means: as previously said, factual content is more easily expressed verbally than spatial and procedural content, for which visual means seem more suitable. At Tholos, spatial elements are visually displayed but the only procedural information that takes advantage of VR’s dynamic potential is the navigation around buildings and eventually the construction of the Attalus’ Stoa. This might justify why visitors could not remember any specific spatial fact (a part from the impressive constructive events) or, at least, were not able to express these verbally, because they had been stored in a visual way.

Finally, the last reason for our results may be the lack of direct interaction at the VR exhibits and especially at Tholos: in their opinions, visitors manifested that they had especially appreciated the possibility of participation and control at the exhibition, and criticized the lack of these features at Tholos. Some authors [3] have demonstrated that we remember better what we see than what we hear and even better what we do. Therefore, it is possible that, although historical information was provided at Tholos, its poor results in comparison with the exhibition are also due to the passive role adopted by visitors, since all the interaction with the system

was carried out by the museum educators and the former only participated at the final voting (positively mentioned by 9.2% of them). Moreover, because all information was orally superimposed to the navigation and had to compete with the visual input, which in our cognitive system has always a stronger impact, it might have been superficially stored and more quickly forgotten.

In conclusion, and in spite of its novelty and impressive technological investment with regard to visual realism and immersivity, Tholos seemed to obtain the poorest results with regard to its main goal -learning- for four reasons: because of the low relevance of the content in comparison with the exhibition and especially with Kivotos (lack of human presence in the application, unknown subject); because it only presented spatial navigation (visual information stored and therefore not retrievable by verbal means); because of the lack of direct interaction of visitors with the system (in comparison with the Kivotos and especially with the exhibition); and finally because historical information was presented orally (and might have consequently been stored marginally in comparison with the visual input). In this sense, and given the strong impact on visitors of Tholos' technological dimension (expressed in several answers to the questionnaire), this exhibit constitutes the most evident example that VR still suffers from "media hyperbole" [18] and therefore fails to achieve its full potential as an effective communication mediator in cultural heritage settings (where it is supposed to convey knowledge through a transparent, intuitive interface).

On the other hand, this leads us to discuss one of the main benefits of ICT invoked by visitors and guides: that because they are less abstract than books they are considered good for cultural heritage settings and for children. Taking into account the previous argumentation, we could not be sure that visual means are *per se* the best option for children, especially without interaction, because real learning -understood as the long-term acquisition of conceptual, procedural and attitudinal knowledge [13]- can only be achieved through cognitive "effort", that is, a deep and conscious engagement with the content and the process of learning. Moreover, in the case of children, learning is not only about pure memorization of factual content but mainly about developing social and reasoning skills that will configure their competence as adults. In this respect, some cognitive studies [1; 8], have demonstrated that technological applications are not very suitable because learning can only be achieved through systematic training involving abstract means, social interaction, mental representations (imagination) and the whole body, while electronic games and computer learning environments focus almost exclusively on visual aspects, reduce the need for mental representations and tend to isolate the user.

With regard to cultural heritage settings, since these are considered informal learning environments, their goals are traditionally more related with contents and enjoyment than with the construction of reasoning skills. However, considering the effectiveness of texts and hands-on exhibits

evidenced by this and other surveys, as well as the problems of integration of ICT applications within the exhibition design [7] and the social dimension [20,15] provoked by ICT's computational interface and language, can we be sure of their suitability beyond their demonstrated positive effects over attention, motivation and engagement in both formal and informal environments [12, 21]?

We are not yet able to answer categorically this question. We would be inclined to say, given the current amount of empirical knowledge, that the usefulness of ICT is not a matter of age or context but of content and communication: because of their virtuality and audiovisual character, they are useful to combine realistic and schematic elements aimed at showing spatial elements, discovering patterns, emphasizing relevant aspects of dynamic phenomena and making abstract concepts more concrete (as demonstrated by the exhibition's big touch screens). Their reconstructive, immersive and interactive capacity can achieve a sensation of Presence that would be suitable to learn about intangible aspects of cultures through game and discovery strategies [14]. On the other hand, when they are interactive, they overcome the traditional uni-directionality of mass media and allow visitors to modify the content in order to learn through an experimental process or to express their opinion/interpretation of the subject (as demonstrated by the recording screen at the exhibition), which would be coherent with the social function of heritage and its settings.

4. CONCLUSIONS

The work presented in this paper is part of a larger project aimed at evaluating the suitability of ICT for cultural heritage with regard to learning, exhibition design and social interaction, as well as their perception and use by audiences. Here we presented an investigation of the effectiveness of immersive VR for learning about archaeology and the past.

The first conclusion of the survey is the general perception by visitors that all technological exhibits at the Hellenic Cosmos offer a similar feeling of transportation, participation or experience of the past, which is aimed at learning and which makes them better in their minds than books. Taking into account the results of previous visitor surveys that investigated that question [11; 5], we would conclude that this is representative of the general perception of ICT applications in cultural heritage by audiences. It is also worth noting that at the Hellenic Cosmos we found a significant association with gender: women seemed to look more for learning than men, who were more interested in the technological dimension.

From visitors' opinions and recalls, it appears that each exhibit supported a different kind of learning. Tholos and Kivotos were associated with more experiential outputs (which in the case of Kivotos became a real feeling of transportation) and considered suitable for obtaining a global idea of spatial details. This was due to their audiovisual tri-dimensionality,

immersivity and the resulting effects of conscious and unconscious Presence. On the other hand, the exhibition was considered better for learning because it contained factual/historical knowledge, was richer in communication means (with text being the basic one) and allowed interaction and control over the visit.

This evidences a contradiction between the declared purpose of ICT in the cultural heritage field (learning) and the perceived and objective outcomes (experiential aspects, difficulty to recall specific and especially historical contents). The perceived outcomes can be justified by the experiential character of new media, which obviously convey knowledge but probably do so in a different way than the one visitors expect, which is associated to text, exhibitions and factual knowledge. The recorded outcomes are probably due to the fact that ICT's effectiveness is not a function of technology alone but a combination of several factors related with the content (spatial vs factual information, relevance of the subject); the communication strategy (visual versus textual means, coherent methodology of recall); and interaction (active exploration of the resources). In order to be suitable for learning, cultural heritage virtual worlds need to be complete and show not only a visually realistic reconstruction of architecture but a real interactive and meaningful reconstruction of the past, containing active human presence.

And this leads to the final conclusion of the survey, which was related with the common believe that VR is more suitable for children and cultural heritage because its experiential and visual character makes it "easier" and more enjoyable. Our results confirmed those of previous studies concerning learning processes and integration within exhibitions, showing that the usefulness of ICT should not be related with age or context (because from these perspectives, it presents more disadvantages than benefits) but with content and communication. VR's experiential character (if there is full intuitive physical and social interaction) makes it suitable for learning about cultural heritage through the feeling of transportation into another culture. However, this has to be further investigated because the introduction of Presence in the cultural heritage field is very recent. Other applications (aimed at conveying historical knowledge) need to be supported by verbal explanations and direct interaction in order to effectively remain in users' mind. On the other hand, the visual and dynamic character of VR makes it suitable for spatial phenomena; and its interactive potential makes it suitable for discovery learning and bi-directional communication.

Therefore, the answer to the title's question would be that, with regard to learning in cultural heritage settings, VR is not always worth a thousand words; only when the aforementioned specific communication and thematic advantages are useful for the exhibition's purposes and compensate the current drawbacks imposed by its computational interface and language. With regard to this, we need to continue investigating systematically the

effectiveness of old and new applications, and also to experiment with new interfaces, designed from a museological perspective instead of a computational one. In this sense, the VR multi-user application at the Hellenic Cosmos exhibition and a previous study [9] demonstrate that this is possible from the point of view of the physical shape of the exhibit, which can be adapted to support social and museographical integration; but the communication language still poses a major challenge with regard to intuitiveness of use. And this is critical because the software constitutes the real link between the content and the user [6].

The comparison of the different kinds of communication solutions at the Hellenic Cosmos' exhibition might provide some very general guidelines for the "perfect" exhibit (suitable for learning, enjoyable, engaging, easy to use, and suitable for groups), which have remained mostly the same since the first were proposed intuitively by the Foundation of the Hellenic World's researchers [18]. Firstly, it needs to contain different linked elements, including text (for learning) and curious / relevant things (for engagement). Secondly, it needs to be interactive (manipulation makes it enjoyable and suitable for learning) and intuitive (user-friendly interfaces with clear affordances, in order to concentrate on the content). Finally, it needs to allow exploration in group (to be engaging) and integration within the exhibition context.

Technological exhibits are not yet able to provide all these elements together, especially with regard to exploration in group and intuitiveness. This is due, as previously said, to the limitations of the interfaces, and especially of the communication language. At the same time, interaction is also very restricted and consists only of spatial navigation, even though the essential definition of VR makes it suitable for two possible educational applications: real participation in historical events (Presence) or manipulation of archaeological data (discovery learning). We believe that tangible or mixed reality interfaces as well as serious games technology are two of the most promising trends worth being more explored in the future because they allow all the features mentioned here with regard to interaction, collaborative exploration and usability.

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Laia Pujol Tost and Maria Economou
 Museology Laboratory, Dept. of Cultural Technology & Communication,
 University of the Aegean, Har. Trikoupi & Faonos Str,
 Mytilene 81100, Greece
 pujol.laia@gmail.com, m.economou@aegean.gr