

# Virtual Reality as a Learning Tool for Archaeological Museums

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**Abstract.** This paper aims at establishing some initial considerations concerning the use of VR in Archaeological museums in order to establish a theoretical framework. In the first part, it sets out the theoretical foundations for the use of VR in Archaeology and Museums, the latter being an informal learning context in which archaeological knowledge is re-constructed. When taking into account only the theoretical point of view, VR satisfies learners' requirements and even constitutes the link between both domains, but this may not match what is happening in reality. The second part of the paper gathers examples from cognitive psychology, constructivist theory, museum surveys, etc. that show the operation of VR in communication and learning. Analysis of all these practices allows us to draw conclusions at different levels – particularly as regards VR as a learning tool – and to improve on the traditionally vague observations made about attraction, entertainment and spectacularity.

**Keywords:** Archaeology, Museums, Virtual Reality, Learning

## 1. Introduction

This paper is a part of a doctoral research project<sup>1</sup>, which aims at analyzing the use of Virtual Reality (VR) as a means of disseminating archaeological knowledge.

The starting point is the observation of a greater use of Information Technologies (IT) in all stages of the archaeological research process over the last ten years. Archaeological VR is now reaching a certain maturity and can be analysed through the enormous production of its principal course of development: the Virtual Heritage. In this regard, currently available information enthusiastically stresses the advantages of VR for communication, but either does not specify the basis for this or else does so on a very superficial level. On the other hand, the context of museums and education has generated considerable bibliography on evaluation, but does not focus on VR or, as in the case of the Computer Assisted Learning applications, this is limited to the scope of formal education.

As we want to ascertain whether VR is suitable for learning Archaeology in the exhibition, we will articulate this through a broad frame of analysis based on the intersection of four main fields: Archaeology, Museography, Virtual Reality and Cognitive Psychology. These will all be integrated within a global perspective, brining together theoretical issues as well as empirical observations; this in turn will allow us to obtain certain initial guidelines for an effective use of VR in museum-exhibit design.

## 2. Theoretical Basis

### 2.1 VR Definition

VR is not a univocal concept. This can be seen in its origins, given that successive terms were coined to designate each

stage in the transformation of the technology: Artificial Reality, Virtual Reality, Augmented Reality (AR), Immersive Virtual Reality (IVR), and so on. These terms do not mean the same thing; they refer instead to different, often overlapping, aspects of the same complex reality (Pujol 2004). In light of its 30 years of life, the original definition of VR can now be deepened through four different approaches.

The most general point of view is the reflection by Pierre Lévy on the meaning of virtuality. In his important contribution to Philosophy, he presents the idea of culture as a virtual manifestation of our evolutionary process (Lévy 1995). From this perspective, language, thought, dreaming, Literacy, Arts, Engineering, etc. should all be considered as the virtual outcomes of the special capacities of the human brain, and can take form in the enormous amount of different objects we produce. Amongst these, computers are the physical representation of our species' latest stage: the Information Society.

VR can also be considered from a visual – mathematical approach (Barceló 2002, Fischler and Firschein 1987). This conception develops from two fundamental ideas. First, human perception works through meaningful images that are shaped in our visual system from the interpretation of light stimulus. When we are not able to see the whole shape of an entity, our brain completes the blanks with previous information not originated in the current data. We can conclude that people's relationship with the environment is established through virtual models of the same. VR also acts in this way, with the advantage that computers can make hypotheses about missing data in a scientific way. A virtual model is, then, an interpretation of reality following a specific theory to complete the knowledge that we do not have. The second idea is that every virtual model is essentially geometrical, because it is shaped by geometrical units and retinal properties which do not search for an esthetic realism but rather seek to understand spatial relationships and abstract properties (Barceló 2002: 22).

The third approach may be called cognitive or ecosystemic (Forte 2003; Glowczeski 2003) because it conceives VR as a global system to understand and communicate the environment. When we try to understand it, we create virtual representations containing many kinds of interlinked quantitative and qualitative information, which result in some form of dynamic “map”, because we can operate with its contents to produce and communicate knowledge. Compared to the previous approach, such starting points are in different fields, but often join in the same conclusion: VR is a good tool for Archaeology because it is a global system aimed at managing spatial and temporal items and relationships.

The final approach is closest to the VR definition that most have in mind as it describes VR in terms of technological implementation. The description of the type of interface places us in a particular kind of VR – i.e. Window on a World (WoW), Immersive or Augmented – which concerns not only the device but also the relationship with the real world and knowledge about it. Moreover, the new devices and kinds of VR bring with them new concepts such as the Virtual Museum or the Hybrid Reality, closely related to museums. Regaining the initial definition of VR set up by Myron Krueger – computer generated, interactive and immersive – which evolved into the current polysemic concept, allows us to attempt an integrative definition. VR is a cognitive environment, created by computational technology, which operates through the interactive simulation of certain aspects of reality to obtain knowledge, communicate or create works of art. Depending on the goal, it can take different shapes: to date, these are AR, IVR, WOW, and HR. This definition covers all the possible approaches, interfaces or goals.

## 2.2 Theoretical Foundations of VR Use for Archaeological Research and Dissemination

VR is formed by computer generated images. Traditionally, images have been divided into signs, symbols and representations. The last category applies to VR that can be considered a computational iconic “depiction” of knowledge. In general, representations of knowledge facilitate the solution of problems in any life situation because they translate reality into a simplified, known form. But in isomorphic representations, there is a direct structural and metrical relationship between some of the properties of reality and their image (Fischler and Firschein 1987: 78–79). This means that the later is based on a minimum number of conventionalisms (scale only) and makes it worthless to specify the entire domain – as you must do in symbolic-algorithmic solutions – because this is already contained in the representation’s structure. In fact, solving the problem is similar to carrying out a physical experiment in a real situation.

The possibility of dynamically representing geometrical items and relationships is very helpful in testing hypotheses on the archaeological record in a realistic way. But the most transcendental contribution of computational virtuality is that a temporal variable can be added. In this way, VR potentially solves one of the biggest hindrances for Archaeology being deemed a scientific discipline: archaeological record is no

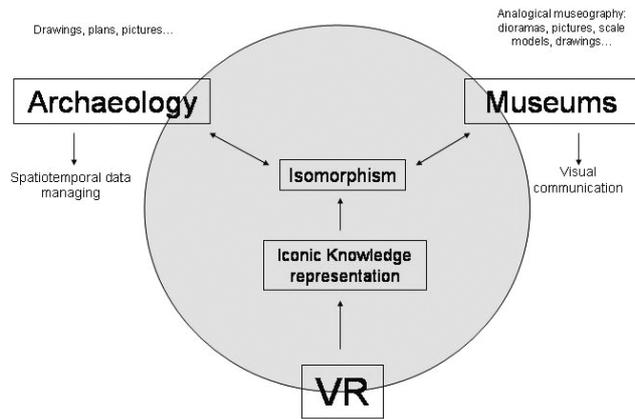


Fig. 1. Theoretical link between VR, Archaeology and Museums.

longer a static dead-end; rather, hypotheses including time –which is the key element of the discipline – can be verified. Iconic representations are also called analogical. However, in VR, images are not analogical, but numerical. The possibility of manipulating mathematical values through algorithms brings the new possibility of analysis, independent from the visual, analogical nature of the object (Deloche 2001: 223–227). In this respect, Virtual Heritage takes advantage of the analogical dimension alone, missing the numerical aspect, more convenient to scientific purposes.

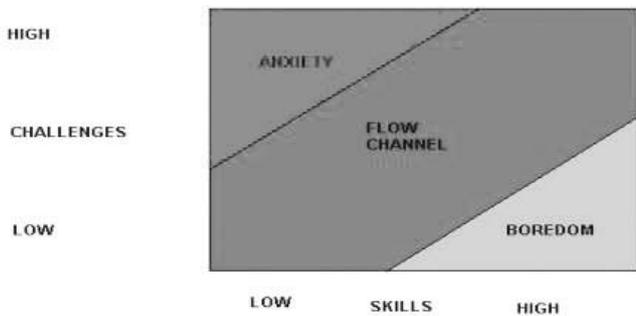
All these aspects are suitable for Museums because they match their communicational needs. Since the first museums were opened, the main channel of communication with visitors has always been the visual. As an image (analogical point of view), VR is the latest generation of substitutes (photographs, scale models) or reconstructions (dioramas) which have traditionally been used in exhibitions (Deloche 2001: 160, 185–205). So, contrary to the opinion of many museum curators, it does not generate conflict within the museographic design and has even been classified under the label “analogical museography” (Flon 2002: 226–227).

But VR can go further. As a dynamic isomorphic representation of knowledge, it allows a “non-expert” approach to Archaeology, contextualizing objects while showing the methodological process that has resulted in the specific interpretation of the past, and comparing it with other possible solutions. This shows us that not only can VR accomplish a positivist goal, but also satisfy the interpretative conception of Archaeology developed by some post-modern perspectives.

## 2.3 Learning in Archaeological Museums

Explanations of how knowledge is acquired have evolved over time, from the first behaviourist postulates to current constructivist conceptions. Defined from this point of view (Clariana 1994; Monereo 2002), learning is a process spanning the whole life, featuring the acquisition of data, procedures and values allowing a person to build up his or her own way of interacting with the world. It depends on personal characteristics (personality, learning style, age...) as well as on contextual variables.

Nonetheless, this process can take place in different contexts that will determine its shape and final results. Since 1973, it



**Fig. 2.** Informal learning context. Flow experiences take place at an optimum level of motivation, possible when challenges and skills are balanced. (<http://web.ionsys.com/~remedy/FLOW/%20%20.htm>).

has been believed that the educative universe is composed of three different but complementary sectors: formal, non-formal and informal. In contrast to non-formal contexts, informal learning environments – where museums are included – have a clear learning goal. But the way in which this is produced is more flexible than in formal contexts such as schools: the museum visit can be defined as a “flow experience” (Csikszentmihályi and Hermanson 1995), where people feel comfortable and are intrinsically motivated to explore because goals are clear, they have control over their learning and challenges match their individual skills.

Informal learning can be the most powerful tool because it more efficiently manipulates the key values of learning, such as emotional implication, interactivity, cooperation, intrinsic motivation, contextualization, clear outcomes and connection to real life (Asensio and Pol Méndez 2003: 64). In fact, we could say that it accomplishes the same function as children’s games. All this gives sense to the word “edutainment”, which can be said to summarize what happens or should happen in museums.

Considering the definition of learning as an interactive meaningful experience, Archaeology is especially suited to education, as long as we take research as the main axis of learning. By simulating the scientific process, people apply the three main methods of reasoning – analogical, inductive and deductive – to construct their own learning. Not only do they acquire knowledge about discipline content, but they also develop their intellectual skills, shifting from a “common sense model” to a “scientific model”. At the same time as it deals with material culture, so it allows people to understand their daily environment and to be capable of relativising opinions..

### 3. Evaluating IT for Learning

With regard to learning, IT have been defined (Monereo 2002: 309) as a meta-medium, able to express, manipulate and combine any kind of symbols (linguistic, iconic, auditory, kinetic...) used by other media. At first, this leads to three main advantages. First, it can represent the same information by different means, so it adapts to different learning skills. Second, it makes internal cognitive processes explicit, it has to represent them. Finally, it allows the interactive simulation of real phenomenon; learning is thus more emotional than rational.

Much evaluation of these theoretical conclusions has been undertaken both outside and inside the museum context. The results may be indirectly applied to VR to constitute a basis upon which to begin setting up an analytical frame aimed at verifying its real potential as a learning tool.

#### 3.1 General Aspects

Motivation, reinforcement and interaction are critical aspects in any learning system. Evaluations in schools (Koester 1993) have demonstrated that IT improve motivation, interest, self-confidence and faster learning. Interaction is the key agent in any learning process because it allows new information to be easily acquired. However, there is a clarification to be made: IT may not be good for all kinds of learning. Due to their features, Traub (Traub 1994) considers that IT are helpful in developing symbolic processes such as language and quantification, but not in developing cognitive (problem solution) and motor skills, because these rely on interpersonal exchange and motion. Indeed, as some recent experimental analysis (Knipp 2003) has shown, cognitive-skill development is an active experience that involves all the senses and not just the eyes and brain. Test scores of three different groups comprising Arts students have demonstrated that spatial conception is better acquired by interacting with real world through the whole body – or even just the hands – than by manipulating flat 3D simulations – such as those on VR – because proprioception plays an important role.

Nonetheless, it must be said that the previous studies were undertaken inside a PC paradigm, which is not as realistic as Immersive VR may be. Behavioural Neuroscience has used a highly immersive and ergonomic 3D system, called VENLab (Tarr and Warren 2002), which allows the creation of a controlled environment inside which human responses to specific conditions can be measured. In these experiments, the critical element provided by VR to brain studies was the ability to credibly break physical laws or disconnect a specific sense. This means that IVR can offer a realistic environment in which human behaviour can be analysed or even modified.

#### 3.2 Constructivism and CAL Environments

Computer Assisted Learning (CAL) has a fairly long tradition of application and evaluation in formal education. Integrated in a constructivist perspective of learning, it is conceived as a computer environment in which students are immersed, and this social contact leads to a conscious and self-paced process of knowledge acquisition.

Studies in pedagogy have stressed the importance of conceptual frameworks in the learning process. If new information has to be retained, it must be meaningful, relevant and organized in a way that allows it to be efficiently processed. The conceptual framework plays an associative role: it adds meaning and relevance to new information as long as this is consistent with previous content. Some evaluations have been undertaken with students to demonstrate the effectiveness of CAL environments as a conceptual framework (Ham 1994). Comparison between groups showed that students using a CAL environment could better judge the

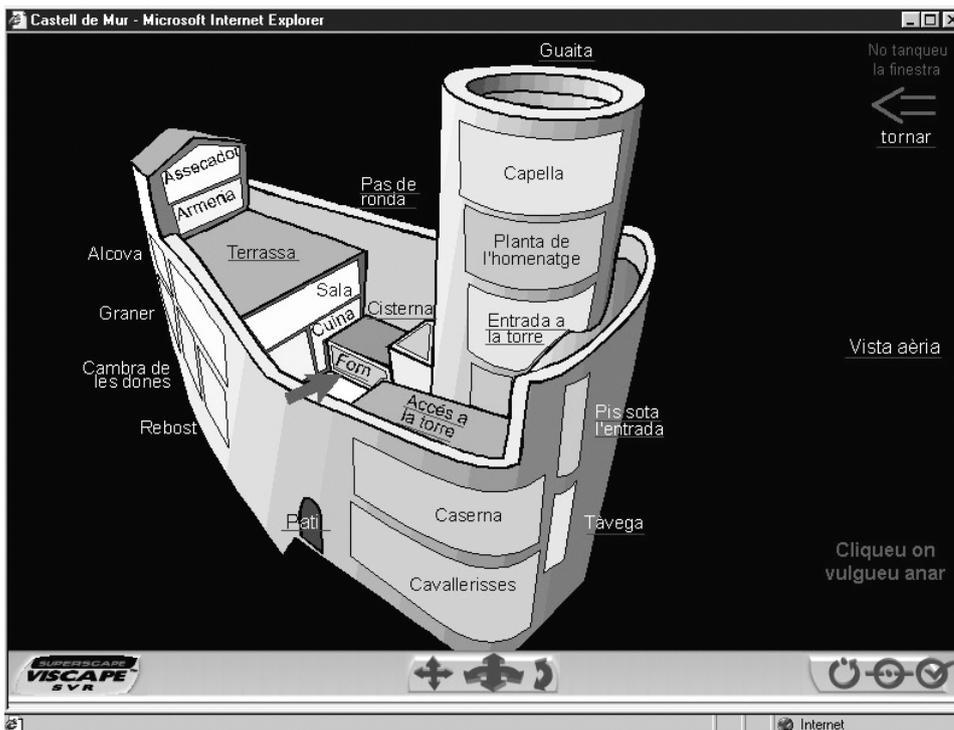


Fig. 3. *El Castell de Mur virtual*. Example of a knowledge metaphor used in Medieval History lectures at Barcelona University <http://www.xtec.es/~ebiosca/index.htm>

relevance of subsequent information; recall and learning were therefore easier for them.

In the case of VR, this associative context takes the shape of a visual metaphor. Thanks to its dynamic and hypertextual potential it creates an interactive knowledge context where different elements can be manipulated to understand given information or topics, linked to the VR image by an iconic relationship. It is the most common application in formal and informal learning environments. Evaluations conducted in the former (Harper et al. 2000) have given evidence of its potential as a learning tool because it makes learning possible by *doing* and so improves motivation. VR is therefore closer to Multimedia than to scientific VR because information is obtained *through* objects and not *from* them.

Constructivist theories also stress the importance of self-consciousness. In this respect, learning is no longer conceived as a passive process but as a meaningful experience where learners are aware of what is happening and have control over it. CAL and other interactive applications such as VR seem to be appropriate because there is feedback between content and user, who explores the computational world while being conscious of his or her decisions. Questionnaires were completed by students after some weeks learning a specific topic. Their answers were significantly different: students who had been assisted by computer environments were more aware of their mental models and how these were changing with learning (Antonietti and Cantoia 2000). The conclusion drawn from this evaluation was that CAL is not only useful for sensory and cognitive skills; it also accomplishes a meta-cognitive function because it stimulates abstraction, imagination and reflection on our implicit assumptions about the world.

VR can be even more suitable than CAL for this meta-cognitive function because, as it is made of images, it

concretizes the abstractions of written descriptions; therefore gaps, especially in the archaeological context, are made more evident. On the other hand, these visual models have the potential to make the methodological procedures underpinning the final result explicit and so allow the debate between interpretations and hypotheses. This issue demonstrates the epistemological limits of our current conception: Archaeology cannot provide the level of detail that Virtual Heritage demands of it.

We have previously stated the role of VR as a particular representation of knowledge. Studies have shown that people better understand a domain when they control its representation systems: for example, language for self-expression, formulae to operate in Maths or even pictorial conventionalism by which to appreciate the Arts. On the other hand,

Cognitive Psychology has long since demonstrated that images are more suitable than abstract symbols when looking for patterns (Wood 1999). This means that in contrast to what people intuitively accept, a picture is NOT always worth a thousand words. Experimental tests (Panagiotakopoulos and Ioannidis 2002; Scanlon, et al. 1998) have demonstrated that CAL environments are particularly useful when dealing with movement, graphics or sound because they allow patterns to be more easily understood. In other domains, the strong correlation between good scores and the use of computers disappears. These results justify the role of VR as a scientific model and a means to communicate spatial knowledge, but we have to take into consideration that it requires communicative skills of a more complex nature, as the user needs to be familiar with the interface language. As further studies will show, this is not always the case, especially with adults and older people.

### 3.3 User Characteristics and CAL

It is also important to know if the user's characteristics influence VR use. Studies with CAL may provide a starting point. These have shown that only certain specific variables show significant differences between test groups.

General demographic variables, such as gender or age, do not influence results. On the contrary, previous experience has a strong effect on these (Shaw and Marlow 1999; Vance Wilson 2000). Familiarity with computers allows better manipulation and this increases motivation.

With regard to personality, experimental tests tried to correlate the 16 Jungian types with the final scores and only one type provided significant results: sensing-thinking people, strongly opposed to intuitive-feeling people, felt more

comfortable when learning with computers. Cognitive styles were also tested and, again, only theorist learners appeared as a meaning category. Factor Analysis showed that they find IT more impersonal and prefer traditional interpersonal forms of education (Shaw and Marlow 1999; Vance Wilson 2000).

### 3.4 What Videogames Can Tell Us

Videogames are now one of the most extended leisure resources and their industry leads graphics research to such an extent that it is influencing archaeological applications through what is called "Low Cost VR". Videogames also interest cognitive psychologists because they are in some way transforming children's games and, consequently, their learning and maturation.

Experiences with videogames have provided some scientific conclusions (Giró 2003) that can be applicable to VR as a learning tool in museums, because they have two points in common: with regard to the interface, interactivity; with regard to learning, the characteristics of museums as an informal context.

Videogames improve the ability to manipulate visual information and spatial imagination; but, at the same time, they stimulate visual skills at an age where language skills are being developed. Concentration may also benefit from videogames because they are multitasking. (However this may also prevent children from a fuller exploitation of each task). Videogames stimulate the ability to anticipate, to make fast decisions and to carry out certain actions, but violent games can induce aggressive behaviour and shy children may withdraw into themselves.

As regards sensory-motor skills, videogames help in developing hand-and-eye coordination, but screen flickering strains the eyes and restricts sense activation to vision. Finally, immediate reward increases self-confidence, but in real life this may well lead to frustration.

## 4. Conclusions

VR has theoretical links with Archaeology and Museums but, as previous evaluations with CAL and other IT have shown, we need to carefully consider its use because there are advantages and disadvantages to be taken into account. It seems that VR could accomplish three main functions (perceptual, cognitive and meta-cognitive), but only in certain specific circumstances: when dealing with movement, graphics and sound. From an archaeological point of view, this means dealing with spatio-temporal data that, unable to be manipulated in the present, have to be virtually simulated, which is a first step towards giving scientific content to Archaeology beyond those of field techniques alone.

But when considering VR as a museographical tool, new issues arise. VR does not always suit the exhibition because technological devices are more often designed for a single user and the museum experience is usually a collective one. In the same respect, the museum experience involves all the senses while VR applies only to vision and hearing. Another problem detected in museum evaluations is the conflict

between VR and objects. IT have a different status as well as their own discourse, which could undermine the exhibition's basic thematic thread.

All this has important implications on deciding whether High-Tech displays or hands-on exhibits are more suitable. If we bear in mind the definition of VR, a general conclusion can be extrapolated from the evaluations made. VR is not a substitute for material culture nor, in comparison to the hands-on option, does it provide an adequate tool to physically interact with such culture (i.e., excavation simulator, etc.). That said, however, VR can be a good tool for museums as a visual model and as a simulation, aimed at managing spatiotemporal data and at understanding the methodology and inference procedures specific to Archaeology.

## Note

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