Exploring the Value of Audience Collaboration and Game Design in Immersive Virtual Learning Environments

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ABSTRACT
Informal learning in public spaces like museums and location-based entertainment venues is increasingly popular during the last years. Especially in technology-enhanced museums such properties as Virtual Reality, Game-Based Collaboration, and Immersive Displays are considered to bear significant educational value. After extensive literature review we have come to the conclusion that little to no research has been carried out on the learning outcomes of these powerful properties. Thus, the scope of our research is to investigate the learning efficacy of an integrated schema of audience collaboration and game design in immersive virtual reality environments. In order to achieve this, we are going to build and evaluate a theoretical framework that supports collaboration within an audience of 9-14 years old children.

Categories and Subject Descriptors

General Terms
Human Factors

Keywords
Audience Interaction, Informal Learning, Virtual Reality, Location-Based Entertainment, Collaboration, Games

INTRODUCTION
The notion of free-choice or informal learning has become more and more popular over the last decade, especially for young children. It is a standard practice nowadays for classes to visit museums in order to provide out-of-school pedagogy to students. Science museums, planetariums, physical history museums, are considered adept sources of knowledge where children can ‘absorb’ information at their own pace. But which are the ingredients that constitute such spaces as powerful sources of meaningful information? We will examine the most reputable pieces of state-of-the-art technology residing in contemporary museums and strive to combine them in a meaningful way in order to facilitate learning in groups of school-aged children.

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By extensively reviewing related literature we have come to believe that the most successful learning tools in today’s children’s culture include Virtual Reality environments, Interactive applications, Collaborative work and Games. If we integrate all these in the Immersive displays available in the technology-enhanced museums proliferating over the last years, we argue that they can bear immense learning outcomes. In order to base our assumption we will start by briefly looking into the most common learning theories and identifying the ones that can be aptly applied to the informal learning settings of contemporary museums. Then we will elaborate on the educational value that these tools can bring to the knowledge-hungry young visitors of such museums, referring to the most prominent related work. We conclude by explicating our proposed integrated schema, stating our future steps and the desired outcomes of our ongoing research.

LEARNING (IN MUSEUMS)
Different learning theories have evolved over the years and been applied to various educational settings. Initially studied by psychologists like Pavlov and Skinner, learning was considered to be a change in behavior which resulted from external stimuli. Cognitivist psychologists like Bruner, Piaget, and Dewey advocated that it is through experience, exploration, and active engagement that learners come to understand the world around them. This view of learning, widely known as constructivism, is the perfect match for the technological museum setting where young visitors are asked to interact with exhibits and construct knowledge [6].

Vygotsky shifted the constructivist theory one step further by emphasizing the importance of social interaction in fostering learning and consequently the child’s development. Among the same lines rests the theory of situated cognition whose proponents argue that learning is a process of enculturation supported by social interaction and the provision of contextual features which allow authentic activity. Practices stemming from these theories lead researchers (including us) to believe that the museum is a fruitful setting for contextual learning where visitors make meaning and find connection in relation to some place or situation by engaging in authentic activities [3].

Let us now examine how these learning theories have been exploited by the aforementioned tools of children’s culture.
MEANS OF EFFECTIVE LEARNING

In today’s world of abundant information, teachers, parents and children themselves strive to find sources of meaningful and effective out-of-school learning. Common resources like the Internet, video games, edutainment software are ample containers of knowledge but lack a feature proved to have a great impact on learning: social interaction. Besides the unquestionable social nature of children, it is quite difficult for parents to accommodate the vigorous urge of youngsters towards hi-tech gimmicks. Location-Based Entertainment (LBE) attractions come to the rescue by providing collaborative learning through play, in the wrapping of the most technologically advanced buzzwords: Immersive Virtual Reality Environments.

Collaborative Learning

Sociality is an innate characteristic of children; the social aptitude which allows children to communicate with other non-acquainted children, be they classmates, playground “friends” or a totally unknown child in an attraction site, so fluently, is a remarkable property. Moreover, children are rather accustomed to eagerly adopt the role of the learner and assimilate instructions from a teacher or exercise apprenticeship within a group of more competent peers.

These attributes are what led researchers to exploit collocated collaboration in computer-supported learning environments and develop applications that foster cooperation between children. Such studies investigating children’s collaborative interactions, initially performed with two users using a monitor and two mice, have shown that engagement in the learning activity is ensured by providing simultaneous interaction with the environment, instead of switching control [7]. More recent research has tested the efficiency of children’s collaboration using a tabletop display over the conventional manipulation of physical tools [9]. Preliminary findings have shown that children adopt assertive strategies in order to gain control and contribute to the shared space.

Corollary of such findings is the belief that children seek more control during their interactions with computers and collaboration with other children. By adding to this fact the capacity of LBEs to accommodate more participants simultaneously, we come to the conclusion that there is a great need for group interaction activities (“group” in the sense of classroom-sized audiences which commonly visit informal educational settings, like technological museums).

Such types of group collaboration we call Audience Collaboration and we will review it further towards the end of this paper.

Game-Based Learning

Another inherent characteristic of children is play; we all grew up through playing with toys and exploring the world around us. This fact sets off a major flaw of the school education system, that it is boring, slow and mostly out of touch [12]. This calls for Papert’s view of constructionism, which is built on the assumption that “children will do best by finding (‘fishing’) for themselves the specific knowledge they need” and that “organized or informal education can help most by making sure they are supported morally, psychologically, materially, and intellectually in their efforts” (p.139). And what is a better way to educate the “computer and video games generation” than adopting its properties and making learning fun for students, trainers, parents and everyone involved in the learning process [13].

In accordance with such beliefs many researchers have studied the potential benefits of bringing video games into education and came up with a group of virtues that make games such good learning tools. More specifically children’s interactions in the virtual worlds of games have been argued to account for the development of situated understandings, powerful identities, effective social practices, and shared values [16]. Other advocates of the tremendous educational potential of games emphasize that by exploring ideas in virtual worlds players are encouraged to solve problems collaboratively, and through contextual peer-to-peer teaching participate in the creation of learning communities [17].

Adverse opinions about the educational value of games argue that they promote aggressive behavior, an individualistic attitude, and abstinence from other leisure activities. However, independent interviews with 7 to 14 years old children of the ‘computer gaming culture’ have shown that games do not interfere with other activities and do not lead to social isolation; instead it is with the company of friends that the majority of children enjoy most their favored leisure activity [5].

Most of the studies in the field of game-based learning praise the beneficial properties of the virtual worlds that video games usually mobilize. But what if we exploit the added value of Immersive Virtual Reality (available in many LBEs) in order to enhance knowledge acquisition?

Immersive Virtual Learning Environments

Virtual Reality (VR) is regarded as one of the most notable tools of informal education. Its unique features of autonomy (human behavior), interaction (real-time control) and presence (real world analogy) [19], constitute a highly respectable medium for imparting knowledge through constructivist learning. When VR applications ‘immerse’ the user in the virtual world with the use of multi-sensory modalities (visual, aural, tactile), having learning as their primary objective, we refer to them as Immersive Virtual Learning Environments (IVLEs). IVLEs have been greatly investigated during the last fifteen years, in order to assess their efficacy, mainly, on conceptual learning.

Most of the studies performed during the ‘90s mobilized Head-Mounted Displays (HMDs) to facilitate immersion in the virtual world and their subjects included mostly science. An extensive research conducted in this field is Project ScienceSpace [2], which concluded that IVLEs enhance student’s abilities to conceptualize abstract scientific ideas. No matter how rigorous this study was, it lacked the characteristics eminent in today’s LBEs: multi-user participation, social interaction, collaborative play.
Another example of IVLE which included collaborative learning through play, was the NICE Project [14], in which two physically distributed groups of 7 to 8 children used different immersive VR setups (CAVE™, ImmersaDesk™), in order to cultivate and tend a virtual garden. Results revealed that, besides the hardware usability problems, the leaders-drivers of the experience were largely the ones who perceived the conceptual model and expressed higher degrees of presence and engagement. This finding supports our assumption, that it is the meaningful interaction of all the participants of an LBE experience that is the leverage for increased enjoyment and positive learning outcomes.

Along the majority of studies which investigated the benefits of VR for learning scientific concepts, very few have assessed the impact of either its immersive or interactive component on virtual heritage environments. An exception to this is a project which evaluated the impact of an immersive panoramic display on learning about an Egyptian temple [8], and revealed that visually immersed students availed themselves of better support in their learning activities. Although interactivity is an indispensable part of IVLEs, we refer to it separately because we believe it constitutes the cornerstone of effective learning in VLEs.

**Interactive Learning Environments**

Despite its implicit and widely documented impact on learning in Virtual Environments, interactivity has rarely undergone formal assessment. An exploratory study about its benefits in teaching geometry with diagrammatic representations [11] did not provide the expected learning gains of interacting with the 3D system. Furthermore, this study included desktop VR systems and was conducted with university students. A more recent research on the effects of leaning on primary school children interacting in a CAVE-like setup in order to learn about fractions [15] revealed that interactivity promoted skill and problem solving but could not be accounted for conceptual change.

As with IVLEs, research on the impact of interactivity on learning has been solely focused on teaching scientific concepts, instead of factual information. Storytelling is a key element for imparting factual information, and falls in with the recreational character of LBEs which call for engaging learning games, where audience members collaboratively create their own stories as they experience them [18]. This lack of real mass interactive learning experiences, forced us to suggest as a solution the integrated schema briefly reviewed in the following section.

**AUDIENCE INTERACTION IN COLLABORATIVE IVLEs**

*Audience Interactivity* is a fairly new and unexplored field, and refers to the process that a large number of co-located people engage in interacting meaningfully with the content presented to them on a large-scale display. Such practices can be usually found in LBEs holding planetariums or dome theaters, which can accommodate such a large audience. No matter how rapidly such venues have proliferated over the last decade, they still lack either the infrastructure or the will to implement and evaluate such mass interaction systems.

Various methods have been tried to achieve interaction in such systems, the most prominent of which are the mass-audience polling device Cinematrix™, motion analysis techniques and custom joypad setups. Among the very few cases in which researchers ventured to experiment with this technology, are two productions on science education [4] which employ Cinematrix™ paddles to selectively present information about cell biology and the brain, to an audience of 150 people situated in a planetarium. Although this work was very promising, as concluded by informal observations, there was no formal evaluation carried out to assess the efficacy of mass interaction for facilitating learning. Other research efforts with a larger audience participating in interactive games include the work of Maynes-Aminzade et al. [10], who experimented with facilitating mass-interaction by means of motion tracking techniques and laser pointers. Although this work still does not include any formal critique methods, we agree with its conclusions that “the greatest challenge lies not in developing the technology for audience interaction, but in designing engaging activities”.

**FUTURE WORK**

The list of works referenced in this paper is by no means exhaustive, but we consider it to be indicative of the research carried out so far in the field of audience interaction. However, we believe that there is a considerable gap in this field, concerning the integration of audience collaboration with games in order to facilitate learning in IVLEs for children. We have been experimenting with this subject for the past two years, developing immersive, interactive VR productions for the digital dome “Tholos”, of the cultural center “Hellenic Cosmos”, located in Athens, Greece. Although the used paradigms of audience interaction (using a keypad) are fairly simple so far [1], we find that the impact they have on school aged children are most intense.

Thus, we strongly believe that group interactivity in conjunction with game design in such an immersive space as a digital dome, has immense potential to learning. Our efforts are directed towards developing an integrated schema possessing the following features and attributes:

- A combination of first and third person world view, according to the type of interaction (individual or group).
- Individual avatar representation and manipulation in order to increase empathy and, eventually, engagement.
- On-the-fly formation of groups which will be assigned with suited tasks, fulfilled only through collaboration.
- Allowance of wrong choice and provision of multiple paths, as a means of increasing free-choice interaction.
- Guidance and interaction facilitation by a human agent impersonated as an avatar in the virtual world.
- Creation of a narrative from the lived experience and distribution to participants, in order to foster discussion in other contexts (e.g. classroom, home, personal research).
As a next step we are going to build a theoretical framework which will ground our assumptions and provide the substructure for the proposed integrated schema. In order to test our hypotheses we are going to develop a game show for a digital dome (hosting an audience of 130 people), supporting the aforementioned properties. We consider ancient Greek Mythology as an appropriate subject for the primary method, with questionnaires and interviews as secondary resources of gathering useful information.

CONCLUSION
We have briefly investigated the ingredients that could very well provide effective means of informal learning in public spaces like museums and most aptly LBEs. Our ongoing research involves building a theoretical framework for evaluating our hypothesis that, by developing meaningful interactive, game-based scenarios that facilitate collaboration in Immersive Reality Environments, we will manage to leverage learning in an audience of school aged children.

REFERENCES