Supporting Social Engagement for Young Audiences with Serious Games and Virtual Environments in Museums

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ABSTRACT
Considering the shift of museums towards digital experiences that can satiate the interests of their young audiences, we suggest an integrated schema for socially engaging large visitor groups. As a means to present our position we propose a framework for audience involvement with complex educational material, combining serious games and virtual environments along with a theory of contextual learning in museums. We describe the research methodology for validating our framework, including the description of a testbed application and results from existing studies with children in schools, summer camps, and a museum. Such findings serve both as evidence for the applicability of our position and as a guidepost for the direction we should move to foster richer social engagement of young crowds.

Author Keywords
Museum learning; game-based learning; co-located collaboration; audience interaction; experimental studies.

ACM Classification Keywords
K.3.1 Computer Uses in Education: Collaborative Learning; H.5.3 Group and Organization Interfaces: Synchronous interaction.

INTRODUCTION
Museums are complex learning environments called to satisfy the diverse interests of large crowds during a limited time visit. One of their most popular audiences is school groups visiting the museums with some learning agenda or for free exploration. In either case students usually explore the space by themselves or are exposed to predefined group experiences, largely deprived from the social interactions for the whole group afforded by the nature of the space. We propose that technology allows for more audience involvement opportunities in museums, especially for engaging students with complex educational concepts and processes.

Interactivity has been shown to be a significant component of visitor satisfaction by means of enabling multi-sensory dialogue, exploration/discovery, cultural connections, empowerment, uniqueness, and construction of meaning [1]. Moreover, digital games and high-end technology are for years an indispensable part of children's culture, both in their leisure time and even at school [24]. Quite a few attempts have been made to merge these themes in the museum arena [5], but they are mostly addressed for individual or family learning experiences. Attempts so far to involve large audiences are restricted to auditoriums, mostly with specialized and proprietary technology (e.g., [13]), where social interactions are limited if not prohibited due to space constraints. We consider that existing affordable technologies can be exploited to benefit the social engagement and collaboration of large visitor groups for learning purposes.

Combining our expertise in developing educational experiences with state-of-the-art technology for large audiences [10], investigating the impact of virtual reality (VR) on cognition [25], and using digital media for teaching science in renowned educational organizations [9], we came to appreciate the power of games and virtual reality to engage young audiences with cultural heritage. Thus, our position supports the potential to socially engage large student audiences with complex educational material by integrating these technologies in a museum context. In the following paragraphs we first present the conceptual framework used as the basis of our position with support from the literature, and then the experimental approach we followed to validate our hypotheses, including the most important findings from our work so far. We conclude with future work and the direction we suggest researchers should take to better understand the potential impact of the proposed framework for museums.

CONCEPTUAL FRAMEWORK
After exploring the major theories about learning and interactivity, and research work being done with collaborative virtual environments (CVEs) and serious games, we extracted those elements that we think can nurture the type of free-choice learning happening in museums. More specifically, collaborative games and VEs are two technologies that have been extensively studied for their educational benefits, while the *Contextual Model of Learning (CML)* is a framework that has been suggested to predict free-choice learning in such spaces [15]. The main premise of our framework is the integration of the CML with collaboration in gaming VEs, for enhancing the museum visitor experience and facilitating learning in (large) student groups.

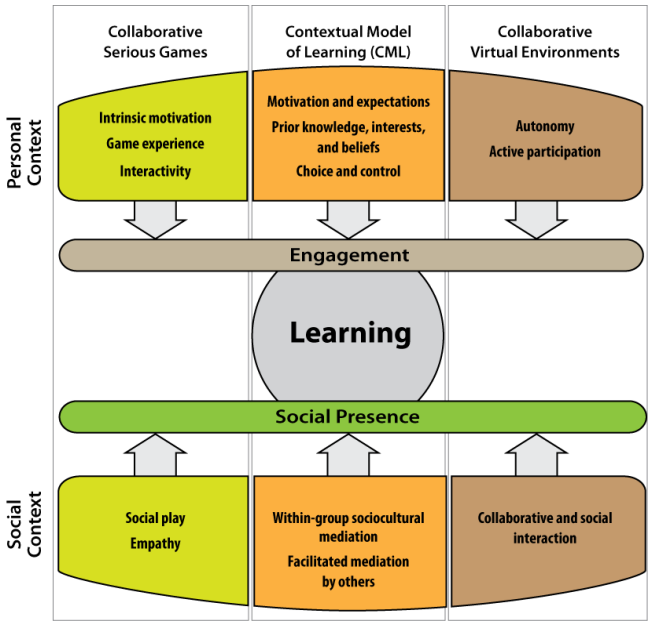

Figure 1. The conceptual framework of our research position.

Framework Rationale

Our decision to combine these technologies with the CML stems from the fact that in a social setting, all of them can nurture learning in two different contexts: the *personal* and the *social*. The personal context includes all the elements and the CML factors that have been shown to affect the individual experience of the game/VE user or museum visitor. These elements have been connected to enhanced *engagement* (e.g., *interactivity* and *autonomy*), which in turn has been shown to increase learning in some situations. For example, Malone and Lepper's theory of *intrinsic motivation* for improving learning outcomes by making learning more fun, and thus more engaging [22], is such an example from the serious games arena. Moreover, students' *active participation* with imaginary worlds that are ingrained in their cultural background—by means of *beliefs*, values, and *expectations*—is believed to increase their emotional involvement and consequently learning [14]; an example from the realm of multi-user VEs. Similarly, the CML predicts the importance of *motivation*, by meeting visitor *expectations* and satisfying their *interests*, for increased learning through sustained engagement during a museum visit [15].

The social context involves the technological elements and CML factors that are believed to contribute to the enhanced social experience of the collaborative game/VE users or museum group visitors. Elements such as *social play/interaction* and *empathy* in collaborative computer-mediated environments have been shown to increase *social presence*, especially when participants are working with or competing against friends [17]. Even in distributed collaborative VEs, the sense of being together (social presence) has been shown to contribute to increased enjoyment, enthusiasm, and improved knowledge and skill acquisition [6]. At the same time, the CML predicts that increased learning derives from the opportunities for *within-group mediation and facilitation* (by more expert peers or guides), afforded by the collocation of visitors in the museum space [15].

Figure 1 depicts our conceptual framework, which identifies engagement and social presence as significant contributors of learning, and illustrates how they are affected by the personal and social context of collaborative interactions between children and technology. We suggest that this framework is helpful in arguing for our proposed position, allowing us to better present the importance of these technologies for supporting situated learning and enhanced audience involvement of young visitor groups in museums.

It is one of the basic goals of our framework to assess the effectiveness of the integration of the elements of the involved technologies and the social context factors of the CML during collocated collaboration, for increasing social presence and eventually learning. Such elements and factors have been examined in isolation about their impact on learning, and we hypothesize that their integration bears considerable potential for the orchestration of learning, in collocated groups of students (such as the ones found in museum group visits). Following our research questions, we present our testbed application and elaborate on how *orchestrated learning* can harness the situated interaction of students in the same physical space.

Research Questions

In trying to investigate the effective merging of the elements used in our framework for achieving an enhanced museum learning experience for a group of students, we address the following research questions:

RQ1: What is the effect of the level of interactivity on learning in a gaming, collaborative VE (CVE) for more than two collocated participants?

RQ2: What is the interplay between level of interaction, game experience, social presence, and learning during within-group collaboration in physical space?

RQ3: What is the effect of culture, prior knowledge, and the style of information presentation (facilitated or not) on learning using a gaming CVE in a museum-type setting?

RQ4: How does the level of involvement of a large audience of students affect game experience, social presence, and eventually learning during collocated collaboration?

Besides this set of main questions some other sub-questions related to factors that have been shown to affect informal learning, were evaluated. More specifically, we investigated the effects of the experiment type on the outcomes; i.e., how an actual museum visit, and the expectations and motivation deriving from it, can affect enjoyment and learning, as compared to a controlled study environment. Also, we tried to gauge the students' interests and beliefs about the domain knowledge, and make conclusions regarding the degree these have affected their overall experience and learning gains.

TESTBED APPLICATION

In order to validate our conceptual framework, we decided to develop a simulation game that supports collocated collaboration, initially for up to three players and then for a whole classroom. This is a virtual environment that teaches students about olive oil production using a game-style interface. The VE is a steam-powered olive oil factory of the mid-1900s with the actual machinery of the time, which players have to operate in order to produce olive oil. Figure 2 depicts the interface with two players, after performing a collaborative task (i.e., attach a belt between two pulleys); a more detailed description of the game and supported actions can be found in [2]. This application is our test bed throughout the whole research, with modifications that enable us to respond to our research questions. Our audience is middle-school students as both the dominant visitors of informal learning spaces during school field trips and avid users of gaming technology.

The topic was chosen for various reasons. First, due to its suitability in enabling us to control the first two key factors of the CML's personal context [15]: *motivation and expectations*, and *prior knowledge, interests, and beliefs*. Testing the game with different populations, having diverse cultural backgrounds, interests, and motivation to learn about the topic, allowed us to assess the effects of these factors on the game experience and learning outcomes (RQ3). Hence, the populations that we chose for our first two experiments come from the American and the Greek culture, with the latter having historically a much larger exposure to the domain knowledge, as one of the largest producers of olive oil in the world. Second, the nature of the application affords ample opportunities for collaborative activities, since the tasks that workers had to do to operate the machinery of the factory at the time involved quite a lot of manual labor. Last, the factory as a closed, well-defined space enables free exploration and manipulation of virtual objects increasing autonomy/control, an empowering feature both for museum meaning making [1], but also for learning through games and virtual environments alike [14,16].

Modes of Visitor Involvement with Digital Games

Since visitor involvement with digital exhibits can vary regarding the number of individuals that can interact simultaneously, we designed two major versions of the game. These versions were used to conduct three experiments with middle school students, investigating a different combination of our research questions each time.

Small Group Interaction and Collaboration

The application was initially designed for one or three players to investigate how the level of interaction and collaboration could affect engagement and learning (RQ1 and RQ2). Students were exposed to the game in groups of three and assumed different levels of involvement depending on the experimental condition. In our first two experiments we compared among three conditions: i) students passively watching someone play the game, with some degree of facilitated involvement by the guide in the second study; ii) one player interacting and the other two negotiating and suggesting plans of action; and iii) all three students playing together and performing the necessary tasks using game controllers. The first condition resembled the typical practice in museums where interactive exhibits visited by a guided group, such as (part of) a classroom, get a more passive exposure to the content of the digital experience. The second one was closer to what is happening when the interactive exhibit supports only one user, in which case the other students gather around and try to participate through social interactions. The third condition was the one we suggested will afford greater engagement and social presence for all participants and eventually improved learning gains.

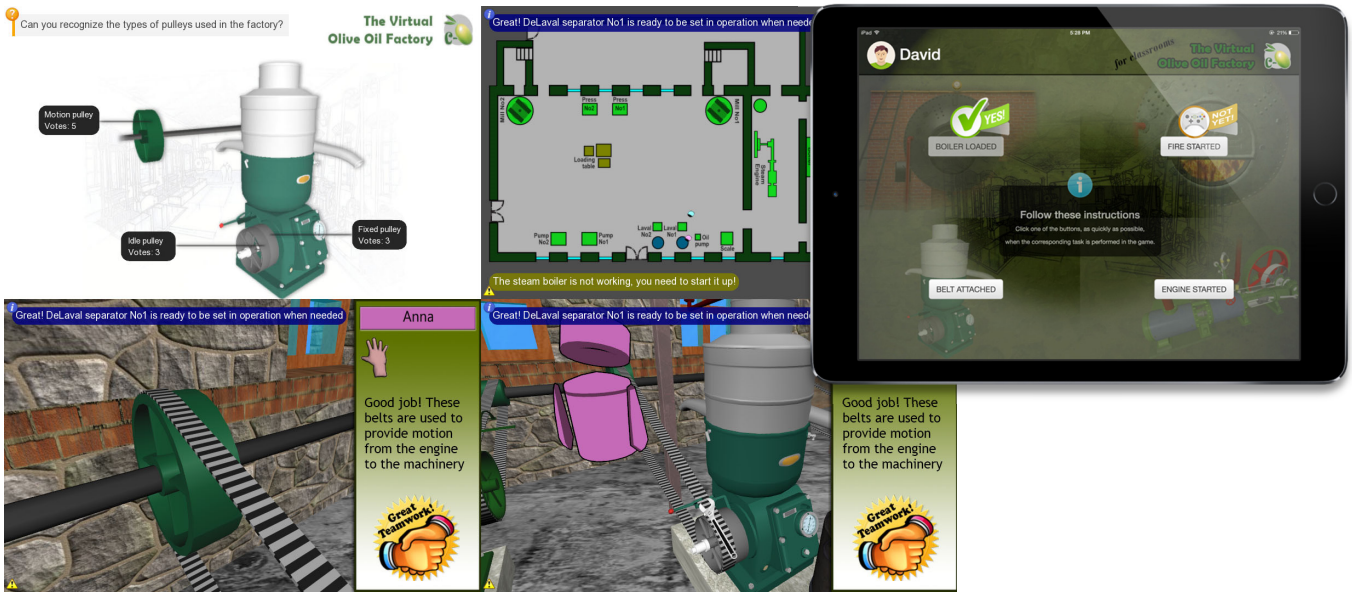

Figure 2. The C-OLiVE game interface for two players and (High) audience involvement, using iPads for a whole classroom experience; (inset) a screen from the Low involvement iPad interface, where audience members register actions happening in the game.

Supporting Audience Involvement and Social Engagement

The second stage, involving a third experiment and a case study in a museum, demanded that the application supports the interaction of a large group, such as a classroom (RQ4). The class was split in two groups: two *players*, who have direct agency in the game using game controllers (similar to the players in our first two experiments), and the *audience*, consisting of the rest of the class, interacting at different points with the game using tablet devices. Our initial plan involved comparing a fully passive condition for the audience, again similar to the common practice in museums, with a more involved one. However, after discussions with teachers we opted for two interactive conditions (i.e., *Low* and *High* involvement), as a means to keep the audience engaged and motivated to participate at all times. The collocated nature of the experience, afforded by the museum visit, can also better nurture social engagement and interactions of visitors when these are mediated by the technology. As an example, (inset) shows the iPad interface in the Low condition, where audience members have to attend and register tasks happening in the game by clicking a button. The High condition involves responding to multiple-choice questions (like the one depicted on the top-left window of the main interface), pointing on the map to guide the players, or performing tasks in the game using the iPads.

Situated Orchestrated Learning

We use the term *orchestrated learning* to denote the type of learning that occurs through the intentional facilitation of coordinated collaborative activities within a VE. Others have used the same term to describe the "coordination of learning episodes," as a means of orchestrating the interactions between learners and resources within a classroom [11]. Based on our own definition, we named our framework, and consequently our testbed application, *C-OLiVE: Collaborative Orchestrated Learning in Virtual Environments*. It has been shown that encouraging collaborative activities by design through the demand of inter-group coordination increases social (inter)actions between participants [7] and according our framework we believe to also have a positive impact on learning.

Moreover, through our extensive literature review, we identified that the basic premise of learning occurring in VEs is the same as the one for free-choice learning spaces like museums. This has to do with the fact that the protagonist of the fictional world is engaged in realistic activities that can change the fate of the world [4], in a similar fashion that the visitor of a museum is engaged with authentic activities that reconstruct real-life experiences and concepts [15]. Similarly, learning in C-OLiVE is achieved by engaging the students in authentic activities within a simulated environment and having them negotiate their actions in the physical space, afforded by the collocated collaborative nature of the game. Situating learners in authentic problem-solving activities is not only considered to be a major leverage of learning in physical contexts such as classrooms [8], but also one of the main benefits of learning within VEs [14].

Furthermore, adopting this metaphor of learners as members of a musical orchestra has other connotations for our instructional approach, besides emphasizing the demand and benefits of coordinated action. Musicians are totally engaged in their performance and their actions are driven by their intrinsic passion for excellent acoustic results, similar to how games like C-OLiVE match the goal and process of the game with the learning outcomes. This engagement with free-choice tasks where extrinsic rewards are absent has been connected to increased sense of the *flow experience* [12], but also to enhanced learning due to its intrinsically motivating power [22]. Additionally, the increased levels of fun and engagement deriving from peer collaboration within groups visiting museums [15], or working together in classrooms [16], might in some cases reinforce learning outcomes.

Another attribute of orchestrated learning, as defined in this work, that applies aptly to CVEs and museums is the rich sociocultural context experienced by the group members. Similar to how orchestra members participate in a shared community of practice, where common goals and understanding are necessary for its success [21], C-OLiVE provides a (virtual) community of workers where players have to negotiate their actions and plan a common route through distributed decision-making. Musicians can assume different levels of participation according to their skill level the same way that C-OLiVE allows players to assume more or less active roles based on their knowledge or gameplay capacity. Finally, learning is facilitated through interactions with more capable peers (musicians or players) or a tutor (conductor or curator), which has been shown to improve individual learning benefits [27]. Likewise, Falk and Dierking consider the *sociocultural mediation by others*, either co-visitors or museum educators, a considerable contributor to the museum contextual learning experience [15].

SUMMARY OF STUDY FINDINGS

We have so far run three experiments with 11-14 years old students, in three different settings: summer camps, museum, and schools. In the first two studies we investigated the impact of collocated collaboration of small groups (three students each), varying the level of interaction/collaboration between the members. The third study was conducted with middle school classrooms, with students split in players and audience, varying the level of involvement of the audience. In all cases we assessed the learning benefit, using a pre/post-test design (domain-specific quiz), game experience, and social presence, using the Game Experience (GEQ) [19] and Social Presence (SPGQ) [20] questionnaires respectively, developed by the Game Experience Lab of the University of Eindhoven, specifically for kids.

Study I: Small Group Game-Based Collaboration

This study was conducted with 47 students during summer camps and after school hours in middle school classrooms. Analysis showed a significant association of learning gains with level of interaction, with higher levels of interaction

(i.e., one or three players controlling the game) affording better score improvement in the quiz. We need to emphasize that this finding came only after taking into account all the variables of the experiment, using a path analysis where we predefined the directed dependencies of the variables based on prior research and our hypotheses. More information of this type of analysis (relating to RQ2) and a detailed report of our findings are included in [2].

Regarding game experience and social presence, which are indicators of an enjoyable social experience during museum group visits, we found that GE (measured as a construct of immersion, flow, challenge, competence, tensions, positive and negative affect) was significantly higher when students had equal agency in the game. Moreover, behavioral involvement (a measure of SP) increased with higher levels of control in both interactive conditions. On the other hand, having control in the 1-player condition elicited more negative feelings, which is an indicator of how unequal control opportunities with digital exhibits can negatively affect the interaction (and eventually visiting) experience.

Study II: Small Group Interactions Mediated by Culture

The second study was conducted in Greece with 156 mainly elementary students (keeping our 11-14 age range), visiting a museum as part of field trip. We followed the exact same procedure as the first study, to enable comparison of results. We only changed the passive condition with one where students' game exposure was facilitated by an expert guide, providing prompts and asking questions at different points. We also gauged the students' perceived prior knowledge on the domain and expectations of their visit using the background survey, as well as their interest being satisfied and visit expectations being met using the GEQ.

Contrary to our hypothesis the facilitated students revealed greater learning gains over both interactive conditions. This was attributed to the overwhelmingly challenging nature of the digital discovery-based learning experience, which seemed beyond the cognitive capacity of this sample group. Our assumption was verified both from observations, but also from the lower performance of these students compared to the ones in first study, besides their assumed prior knowledge due to higher culture-based exposure to the domain knowledge. We consider the differences in the school grade affecting cognitive development, the culture-specific learning styles [26], and leading motive orientation (i.e., play or learn) [18] influenced by the study venue to be the main contributing factors for the contradictory findings.

Game experience and social presence measures followed the same pattern, with increased challenge and tension in the interactive conditions negatively affecting learning, while increased collaboration opportunities eliciting higher sense of being together. Interestingly, perceived interest on the content and visit expectations being met did not affect learning, but was correlated with most GE and SP measures. A detailed account of this study can be found in [3].

Study III: Audience Involvement with Game Exhibits

Our third study was conducted with 507 middle school students playing the game in classrooms, with 476 of them participating in all three days (pre-test, game, and post-test). The results of our analysis have been submitted for publication and cannot be discussed here, but we anticipate that we will be able to present them during the workshop. There were quite some important findings concerning the effects of agency in the experience and involvement level of the audience on retention of information, which we consider to bear significant implications for informal learning settings. Furthermore, running the study in two schools with students of a highly different socioeconomic status, allowed us to interpret the results in light of their varying academic performance (based on official data). This also greatly impacts building interactive experiences for public spaces such as museums, which are visited by a diverse crowd.

CONCLUSIONS AND FUTURE WORK

We have argued for a need to socially involve large groups of students visiting museums in learning complex material collaboratively through digital games, as a growing part of their culture. Using our research framework we set the basis for our position, grounding our arguments with literature on serious games, virtual environments for education, and contextual learning in museums. To validate our claims we conducted three experiments with middle school students, and presented the most important findings as evidence. Overall, we found that learning gains are contingent on the profile of the visitors, with culture-specific learning style and cognitive development defining the best way for information assimilation. Moreover, equal interaction opportunities are a contributing factor for sustained engagement during small group interactions with technology, affecting both the overall experience and the interconnectedness of the participants.

Our next step is to run a case study in a science museum, with our system updated to address the lessons learned from our experiments. This will allow us to validate our position in a real setting, with the diverse crowd of school field trips. At the same time we plan to analyze the significant number of recordings and logged game data we have from the last study, to identify patterns of social interactions between the students and their correlation with measured learning, game experience, and social presence outcomes. That way we can better evaluate the effectiveness of the proposed framework (and our position) in supporting large group social engagement with complex educational games for young visitors.

As museums move towards a richer dialogical engagement with their audiences, both within their physical constraints but also with online and social media platforms, they should integrate new technologies to better serve and attract the crowd's interest. Providing memorable experiences for their young audiences and sustaining their involvement through socially rich experiences that speak in their own language, can fulfill one of the most important contributions of museums, "fostering human relationships and strengthening a sense of communal purpose." [23].

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