

C-OLiVE: Group Co-located Interaction in VEs for Contextual Learning

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ABSTRACT

In informal learning spaces employing digital content, which groups of students usually visit, visitors do not get adequate exposure to content and if they do, it is usually in a passive style instruction offered by a museum docent to the whole group. This research aims to identify which elements of co-located group collaboration, virtual environments, and serious games can be leveraged for an enhanced learning experience. Our hypothesis is that synchronous, co-located, group collaboration will afford greater learning compared to the conventional approaches. We developed C-OLiVE, an interactive virtual learning environment supporting tripartite group collaboration, which we are going to use as a test bed to respond to our research questions. In this paper, we discuss our proposed research which involves exploring some benefits of the involved technologies and proposing a list of design guidelines for anyone interested to exploit them in developing virtual environments for informal learning spaces.

Keywords: Informal learning, collaborative virtual environments, game-based learning.

Index Terms: • **Applied computing ~ Interactive learning environments** • *Applied computing ~ Collaborative learning* • Human-centered computing ~ Empirical studies in HCI

1 INTRODUCTION

During the last years, digital exhibits have become prevalent in contemporary museums employing a variety of state-of-the-art technologies, like touch panels, interactive surfaces, games, and virtual environments, for communicating content to their visitors. However, in such free-choice learning spaces employing digital content, such as games, (groups of) students are either left to their own devices to control their learning by exploring the space/game, or they attend a presentation led by a museum docent who is controlling the content. In these extreme cases students do not have the necessary context and/or guidance to facilitate their learning or instruction is too mundane, insensitive of students' individual needs and craving to control the game.

We believe that there is great unexplored potential to exploiting the benefits that these technologies bring to learning, in both enhancing the visitor experience and facilitating learning. Thus, we have explored research work being done with educational virtual environments (VEs) and collaborative serious games for learning, in order to identify the most significant elements that can nurture the type of free-choice (or informal) learning happening in museums.

In the following sections, we initially present the problem space, then our research questions and hypotheses, the work we have done so far, concluding with future work and contributions.

2 PROBLEM SPACE

In order to give a better perspective of where our work fits in existing research, we provide an illustration of the problem space (similar to [1]). Table 1 depicts the different elements of VEs and collaborative serious games that have been shown to affect learning, and the type of learning afforded in museums; starred items indicate elements that are related to our research. Hopefully, this table will be helpful in presenting the scope of the proposed research within the larger body of work which has focused on the learning benefits of the technologies involved.

Table 1. The problem space and elements that the proposed research is related to (indicated by the blue star).

Types of learning supported by VEs: <ul style="list-style-type: none">★ • Procedural knowledge★ • Factual knowledge• Conceptual knowledge• Spatial knowledge
Approaches for studying the value of educational VEs: <ul style="list-style-type: none">★ • Ecological evaluation (complete application)★ • Controlled experimentation (complete application)• Controlled experimentation (simplified learning task)
Elements of VEs related to learning: <ul style="list-style-type: none">★ • Autonomy (control)★ • Active learning★ • Collaborative and social learning• Multiple representations of concepts• Use of space – navigation• Immersion – Presence
Elements of collaborative game play related to learning: <ul style="list-style-type: none">★ • Interactivity (control)• Narration (story)★ • Game Experience/Engagement★ • Social presence• Motivation
Attributes of contextual learning in museums [2] : <ul style="list-style-type: none">★ • Motivation and expectations★ • Prior knowledge, interests, and beliefs★ • Choice and control★ • Within-group sociocultural mediation★ • Facilitated mediation by others• Reinforcing events and experiences outside the museum• Advance organizers and orientation• Design

2.1 Research Questions

In trying to investigate the effective merging of the elements shown in Table 1 for achieving an enhanced museum learning experience we will address the following research questions:

Q1: What is the effect of the level of interactivity on learning in a gaming, collaborative VE (CVE)?

Q2: What is the effect of the type of information presentation (facilitated or not) and prior knowledge on learning using a gaming CVE in a museum-type setting?

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- Q3: How is learning affected by the within-group collaboration in physical space, compared to cues provided in the virtual world?
- Q4: What is the impact of the type of experimental setting on learning?
- Q5: Which are the significant design guidelines for developing an effective CVE for museum use?

Deriving from this set of main questions are more sub-questions which are examining the interplay between interactivity, game experience or engagement, social presence, and learning.

2.2 Hypotheses

Our main hypothesis is that as interactivity level increases, so will engagement and eventually learning. This is based on previous work that has shown a close connection of engagement and learning in VEs [3]. Similarly, social presence and intrinsic motivation, mainly stemming from prior knowledge and expectations, will also be a contributing factor to increased learning. Although there have been lots of studies about the impact of motivation on learning (the most popular one being [4]), not much research has focused on how social presence affects learning.

2.3 Approach

We have implemented a complete application about olive oil production, which we call C-OLiVE: Collaborative Orchestrated Learning in Virtual Environments. The topic was chosen due to its suitability in enabling us to control the first two key factors of the museum learning experience related to personal context [2]: *motivation and expectations*, and *prior knowledge, interests, and beliefs*. 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. This application is going to be our test bed throughout the whole research, with modifications that will enable us to test our research questions. Our audience is middle-school students as both the dominant visitors of informal learning spaces and users of gaming technology. Learning is measured in all cases with the administration of pre and post-tests.

For reasons of brevity we present in Table 2 a summary of our approach in responding to our research questions. Overall, we plan to conduct two controlled and three ecological evaluations; the first four would be experiments for assessing the most important elements considered from the problem space, while the last one is a case study for evaluating the effectiveness of the suggested design guidelines.

Table 2. Summary of our research approach (* completed).

Experiment Type	Research Questions	Elements considered
I – Controlled*	Q1	Interactivity/autonomy
II – Ecological	Q1, Q2, Q4	Interactivity/autonomy Facilitated mediation by others Prior knowledge, beliefs
III – Controlled	Q3	Within-group sociocultural mediation
IV – Ecological	Q1, Q4	Interactivity/autonomy Active Learning Choice and control
V – Case Study	Q5	Overall evaluation

3 RELATED WORK

Various researchers have done studies about the effects of the individual elements under consideration on learning, usually under controlled conditions, but none according to our knowledge has used the integrated setup and audience proposed in this work.

More specifically, VEs and their educational benefits have been studied mainly in the context of conceptual learning. Common examples of such work include studying the effects of VR on learning abstract scientific concepts as was the case in Science Space [5], using high school students in a controlled environment. Collaborative VEs usually involve work with two actively participating students, and in most cases they are distributed among different locations and using different setups. This was the case with the *NICE* project [6], where primary school children had to collaborate in order to tend a virtual garden using different VR platforms, where only one student from the group assigned on each platform could interact with the VE.

On the other end and due to the advances in games and network communications, massively multiplayer online games, and especially their role-playing genre (known as MMORPGs) have been lately exploited for formal and informal learning. Existing platforms like *Second Life*, have been widely used for training and educational purposes [7], although no significant gains in learning have been found besides increased motivation and user experience. Barab et al. [8] have coined the term “transformational play” in their *Quest Atlantis* MMO to indicate the type of learning that stems from transforming existing knowledge and skills by actively participating in dynamic situations. Their game-based classroom showed significantly more learning gains and levels of engagement, compared to a story-based curriculum.

Although this work has been done in the context of formal education with a multi-user online VE, we find its approach greatly related to our research. Additionally, we plan to exploit the *Contextual Model of Learning* (CML) for enhancing the museum experience [2] using lessons learned from collaborative game play research. The contexts of the CML that mostly influence learning in a VE hosted in a museum are the *personal* and *sociocultural* ones; thus we plan to explore the effect of their related factors (the first five in the last cell of Table 1) in the co-located collaborative setup of the proposed work.

4 COMPLETED WORK

4.1 Virtual Environment: C-OLIVE

Based on our research approach we had to first develop the test bed application that we were going to use in our experimental evaluations. The outcome, C-OLiVE, is a VE of an actual olive oil factory of the 1960s in Greece, containing exact 3D replicas of the machinery used at the time (see Figure 1:). The VE is designed to support one to three players and different kinds of game controllers, but we have decided to use wireless Xbox controllers due to their popularity and available outputs. The VE contains a map with avatar location and problem alerts and players have to troubleshoot problems with the end goal of starting up the factory and producing olive oil.

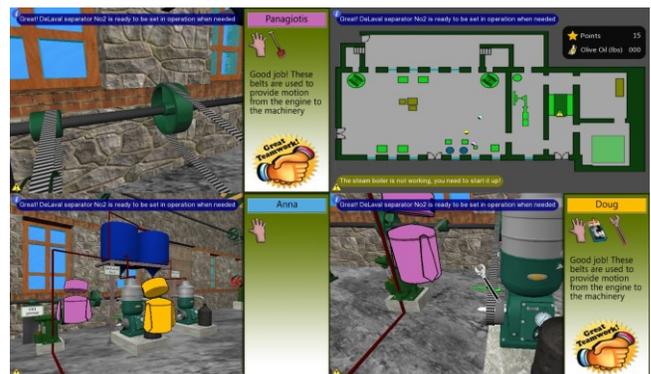


Figure 1: The C-OLIVE virtual olive oil factory used as a test bed.

A state machine is used to store all the information, alert, and interaction feedback messages that are presented during game play. Collaboration is demanded in different parts where workers in a real factory had to complete a task by working together (e.g., lift the heavy olive sacks). When a collaborative action is executed the players involved are notified with a sound and an icon; in Figure 1: the top-left and bottom-right players have completed such a task. Learning is achieved by engaging the students in authentic activities within an actual olive oil factory and having them negotiate their actions in the physical space, afforded by the co-located collaborative nature of the game.

4.2 Experiment I

We decided to run a first study to respond to our main research question about the impact of interactivity on learning. Hence, we conducted a controlled study with 47 middle school students, throughout a period of six months. Students participated in one of three conditions in groups of three: *fully auto* (N=14), where they were watching a recording of someone playing the game; *1-player (1P)* (N=18), where one player was controlling the game and the rest were helping her by indicating problems that needed attention or suggesting plans of action; and *3-player (3P)* (N=15), where all three players were playing using game controllers. The game was projected on a large front-projected 16:9 screen and students were sitting at a distance of around 10ft (see Figure 2.).



Figure 2: Experimental setup (controlled) of the 3P condition.

4.2.1 Procedure

Participants had to complete a background survey and quiz (pre-test) on the domain knowledge (i.e., olive oil production) using an online survey tool 10-15 days before the experiment to avoid priming. At the day of the study they were introduced to the subject with a 5-min video explaining the main processes involved in steam production and olive oil extraction. Then, they got to practice with the controllers and the game through a guided practice session. After feeling comfortable with the devices and the interface they started the main trial (1P and 3P conditions) or watched a video of someone playing the game (Auto condition). Finally, they had to take a presence, engagement, and social presence questionnaire, and complete the same quiz about the subject matter (post-test). An informal interview ended the study session.

The quiz was broken down in three parts: the first had purely factual information taken from the messages in the game, the second asked higher level questions where a combination of information had to be evaluated, and the third was about tasks that demanded collaboration. For assessing presence we used the Slater-Usuh-Steed (SUS) questionnaire. Engagement and social presence were measured using the Game Experience Questionnaire

(GEQ) [9], which is broken down to seven GE constructs for engagement (competence, challenge, flow, immersion, positive affect, negative affect, and tension) and three for social presence (behavioral involvement, empathy, and negative feelings).

4.2.2 Results

Learning, which was our main outcome, was calculated with the difference between pre- and post-test scores. Participants in all three conditions revealed a highly significant gain in learning both in the overall and the partial quiz questions ($p < .001$). There were no significant learning differences between the three conditions in the overall score, which was our main interest. There was, however, a significant difference in responding correctly to the last part of the quiz about collaborative tasks; $F(2,44)=3.465$, $p=.04$. A Games-Howell multiple comparisons test revealed that the subjects in the 3P condition were more effective from the 1P ones ($p=.036$). This effect is diminished when only the non-controllers are taken into account for the 1P condition [$F(2,38)=2.816$, $p=.072$], indicating that the controllers in the 1P condition had a better understanding of the collaborative actions.

There was no difference in presence among the three conditions. As far as the GEQ is concerned, there was a significant effect of interaction level both on positive ($p < .05$) and negative affect ($p < .001$), but also negative feelings ($p < .05$) from the social presence measures. The latter effect is diminished when only the non-controllers are taken into account, indicating their perceived poorer experience stemming from not controlling the game. This last result is also verified by complaints expressed during the interview. None of the remaining game experience and social presence constructs was significantly affected by the treatment. Running a multivariate ANOVA on all seven GE measures, we found a significant effect of interaction level ($p=.016$), which indicates that students in the 3P condition (N=15, $M=4.18$, $SD=.26$) enjoyed the game much more than their 1P counterparts (N=18, $M=3.78$, $SD=.65$); scores were measured only for the interactive conditions on a scale of 1 (not at all) to 5 (extremely).

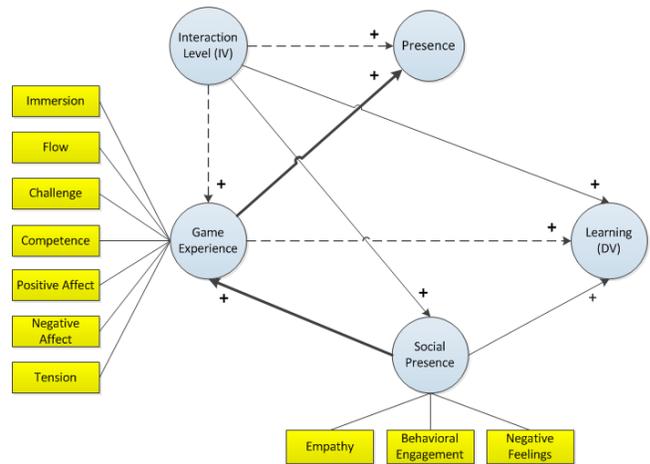


Figure 3: Path model with hypotheses (+) and results (lines). Solid lines are significant at 5%; thick lines are significant at 1%.

In an attempt to explore the combined effect of the independent variable (interaction level) and the self-reported measures (game experience, presence, social presence) to predict the outcome (learning), we decided to use the partial least squares (PLS) data analysis method. We used SmartPLS to setup and test a path model deriving from the literature and our hypotheses. Figure 3 shows the model and the results of the analysis using the same number of cases (N=47) and bootstrapping with 5K samples. We noticed that using this model, interaction level could significantly

predict learning in the presence of the other constructs ($t=2.239$, $p<.05$), with higher levels of interactivity predicted to produce greater learning. Interaction level could also predict significantly social presence ($t=2.055$, $p<.05$), but not game experience or presence. All interactions between the variables as well as our initial hypotheses can be seen in Figure 3.

4.2.3 Discussion

Although the main analysis did not seem to reject the null hypothesis, there were many other interesting findings that point towards the benefits of co-located collaboration on the overall game experience. Besides the statistical findings, our qualitative results from observations, recordings, and interviews indicate that students enjoyed the 3P condition much more than the other two. There were many cases in the 1P condition where both controllers and non-controllers expressed their preference to engage in a two or three-player game, without knowing about our 3P condition. Although learning might be important in such spaces, we should not underrate the significance of visitor experience, as well.

5 FUTURE WORK

Taking into account the lessons from our first study we intend to explore other elements of the problem space and deepen our understanding of co-located collaboration in VEs for informal learning with games (see Table 2 for a summary of next steps).

5.1 Experiment II

The second experiment is planned to be conducted in two different museums in Greece, located in places with rich history in olive oil production. We want to investigate the effect of prior knowledge and interactivity on learning inside an actual museum. Only the 1P and 3P conditions will be used since they have shown to contribute to a better learning experience compared to our passive condition, which is going to be replaced by an expert guide demonstrating the game (Q2). We are going to measure the scores of these three groups and compare them with the scores of experiment 1. Although an improved game will be used in an actual museum space, we can still draw some useful conclusions on the effect of the experiment type (Q4), and prior knowledge and motivation (assumed to differ due to the cultural and background differences between samples) on learning, in relation to the style of information presentation/level of control (Q1, Q2).

5.2 Experiment III

This is going to be a controlled experiment with the intent of understanding how much the social presence afforded by the co-located aspect of the game contributes to learning, compared to other collaborative VEs, like online games and distributed virtual worlds (Q3). Groups of three students will play the game in three conditions where we are going to vary the type of collaboration between three levels: *computer only*, where players will collaborate with the use of user-controlled, computer-generated cues; *physical only*, where players will have to collaborate in the physical space (similar to the 3P condition, which we have used until now); and *both*, where players will be able to choose the preferred mode of collaboration at every point in the game.

5.3 Experiment IV

The goal of this last experiment is to provide some insight on the tradeoff between full control of gaming CVEs, and the derived increased engagement, and the learning and time spent with the specific digital experience. We will assess interactivity in a more fine-grained level while still having three players interact with the game in a museum space (Q4). We will create two additional interaction modes where players will be given less control

compared to the fully interactive 3P mode, which we have used until now. Once more, learning and engagement will be assessed between three interactivity conditions: *guided*, where players will follow predetermined routes and have to make choices at different points; *semi-guided*, where they will be moving between some points but surrender control at others; and *autonomous*, where they control the game by themselves, similarly to the 3P condition of the previous experiments.

5.4 Case Study

Based on the findings of the previous experiments we will refine the application to best support learning of visitors in museum and similar informal education venues, taking into consideration the constraints of these spaces and the lessons learned from testing the key factors of the CML with C-OLiVE. We will then install and evaluate the application in one or more museums, ideally both in the US and Greece. Our goal is to gather mainly qualitative data (observations and interviews), which will help us compile a list of design guidelines for developing engaging, interactive, collaborative VEs for museums using contemporary gaming technology.

6 EXPECTED CONTRIBUTIONS

The benefits of this work derive from our approach on merging the gaming, CVE technology, and museum worlds, for enhancing the visitor experience and its learning gains. More specifically:

- researchers on interactive virtual learning environments will better understand the effect of interactivity on learning and engagement, in co-located multi-user setups
- designers of digital museum exhibits will have a set of guidelines for designing enhanced experiences in museums employing VEs and games for groups of (young) visitors
- researchers/designers of collaborative learning will have a better grasp of the benefits of co-located game play and how it affects social presence and engagement
- curators and exhibit designers will be able to decide if a CVE might be an appropriate medium for disseminating the information they want to their visitors

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