A virtual tour of the Walls of Nicosia: An assessment of children's experience and learning performance

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Abstract
Modern-day museums employ technologically advanced methods and equipment to facilitate the dissemination of information and education of their visitors. Such a system is installed at the Leventis Municipal Museum in Nicosia. An interactive application that runs on a multi-touch table allows the user to navigate through a 3D representation of the fortifications of Nicosia in different historical periods. In this paper, we assess the visitors' experience and learning performance/effectiveness using this system. We compare the results with those achieved using a traditional method, which is by studying printed maps exhibited at the same museum. We performed this comparison with a user study, involving two groups of children, each using one of the two different methods. Results show that users enjoy using the system and that their learning performance is much higher than that of the traditional method.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1. Introduction

Traditionally, museums conveyed information to their visitors through the exhibit of real objects. During the last couple of decades, a new trend is adopted by modern museums; to employ technologically advanced systems for that purpose. These systems can be separated in two categories; those accessible from remote visitors, through online multimedia or VR systems and those systems that are located within the physical space of a museum.

In the first category we have virtual museums, which extend the physical museums in a variety of ways [BH05]. Focusing on 3D representations, a virtual museum may be a digital depiction of the existing museum and its exhibits [PCS*08], [KAC08], or it might include a combination of objects existing in several museums, while in some cases the 3D objects that have been modeled are based on description of historical documents [GCR01]. This category of systems, aims to convey information and knowledge that can be found at the museums, to virtual visitors, that are not able to visit physically the museum.

Systems in the second category, that are located within the

museum, aim to attract more visitors at the physical space of the museum. They provide modern ways of learning while increasing the satisfaction of museum's visitors. They allow the virtual interactivity of the user with a 3D representation of objects or the tour within virtual worlds. This category includes applications that run on VR systems [Rou01], Augmented Reality systems [WWWC04], haptics displays [LTF*04], multi-touch tables [AC09], [Gel06], etc. Virtual worlds combine in a great extent entertainment and education/training.

Several studies have examined such systems for their learning strengths and affordances. Issues such as the learners' engagement and motivation, as well as the increase of learning performance and retention of knowledge have been investigated [AW06], [Nij00], [Hut07]. Evaluation of such systems [TVZ*05], [KSW06], [CIR04] is another main research issue, since they are used by users with a great diversity in their profiles. In this work, we evaluate an interactive 3D application that runs on a multi-touch table located within a museum in Nicosia, the installation is called "the Walls of Nicosia". The evaluation of this application is focused on learning performance and user experience. The

following section presents the application under evaluation. Section 3 analyses the method of this study, followed by data analysis and results. This paper ends with the discussion of findings and conclusions.

2. The Walls of Nicosia

Figure 1: *The touch-table running the "The Walls of Nicosia" application.*

The installation "The Walls of Nicosia" [AC09] is an interactive application that allows the user to have a virtual tour through the fortifications of Nicosia across the centuries. The application runs on a multi-touch table (see Figure 1) which allows for a more natural interaction. Three-dimensional models of the fortifications of the city as well as the most important landmarks, are demonstrated for five historical periods: pre-Roman (villages with no fortification), Roman castle, Byzantine castle, Lusignan Walls and Venetian Walls. Images of these periods can be seen in Figure 2.

The users can navigate through time with the help of a menu that appears on the top of the screen of the table. They can then interact and study the 3D models of the historical period they choose using intuitive gestures. The users are able to zoom in/out, pan and tilt the virtual camera. A helping menu exists on the interface of the application, describing how each of these operations can be performed. A compass, on the top-right corner of the interface, assists the users with orientation. Traditional music is played for each historical period, in order to immerse the user.

The multi-touch table hardware is based on back projection. A projector, connected with the host computer resides inside the table. The final image on the top surface is produced with the use of a mirror that reflects the projector image. This technique is used in order to virtually increase the space within the table and allow us to use a standard DLP project (not a short throw one). The gestures of the user's fingers are tracked using infrared light. For this purpose, they have been used 300 LEDs and a camera with a filter

for capturing mainly infrared light - all placed inside the table. LEDs emit light towards the table surface. When a user touches the surface the infrared light is reflected back and the infrared camera captures that light. Each frame that is captured by the camera is processed in order to detect the position of the user's fingers on the screen.

3. Method

3.1. Research design

This study aimed at assessing users' experience with the "Walls of Nicosia" and evaluating learning performance. Accordingly we created two different types of classes: (a) a traditional one (control group) where children took a guided tour throughout the museum and learned about the walls of Nicosia through printed maps exhibited at the museum and (b) the virtual class where children interacted with the application "The Walls of Nicosia". The two different classes were based on the same learning content and learning objectives and both of them were located in the same place, the Leventis Museum. Teachers of both groups provided to students the same information for the walls, following the same structure for the teaching material, using the two different ways. The study investigated the following research questions:

1. Are there any differences in *Learning Performance* between students of the traditional group and the virtual group?
2. Are there any differences in the *User Experience* between students of the traditional group and the virtual group?

3.2. Participants

The participants for the study were randomly selected from a list of elementary schools in Nicosia. In total 17 children (9 girls and 8 boys) participated in this study from the Elementary School of Ayios Dometios C'. The children attend the 5th year class at elementary school.

3.3. Data collection and procedure

Both quantitative and qualitative data were collected. Two questionnaires were developed:

1. A pre-test questionnaire containing two parts, one part for collecting demographic information (age, gender, year at school) and the second part for evaluating learning performance, i.e. a knowledge test regarding the walls of Nicosia.
2. A post-test questionnaire containing two parts, one part for assessing the user experience and the second part for evaluating learning performance.

The knowledge test as included in the pre-test and the post-test questionnaire was the same. The knowledge test contained 10 multiple-choice questions on issues related

Figure 2: *The five images are representatives of the five periods depicted in the application. From top left we see: the unfortified pre-Roman settlements near the Pediaios River, the single settlement around the Roman Castle that sat at the centre of what later became the walled city, the Byzantine period where the old castle is replaced by a church and a new castle is built on the edge of town, the Lusignan fortifications that enclosed the whole city and strengthened the Byzantine castle, and finally the Venetian walls which were build during the 15th century and still stand today. The later walls were smaller than the Lusignan ones, thus some parts of the city had to be demolished during their construction.*

with the walls of Nicosia as the learning content and the learning objectives of both classes indicated. Representative examples of questions that included in the test are given below:

1. What was the purpose of the walls?

    a. fortification of the city
    b. definition of the city's borders
    c. facilitating trade

2. How many are the gates of the walls?

    a. two
    b. three
    c. four

This test was developed by the research team and its validity was assessed by two experienced teachers who were responsible for conducting the tour. We should note that users in this study were children from 10 to 11 years old. Therefore in order to assess user experience we employed the Smileyometer, which is a tool contained in the FunToolkit. The latter is a well-known and validated tool for assessing user experience with technology when the users are children [Rea08]. Additionally qualitative data were captured by observing the students of both classes.

Figure 3: *Students answering the pre-test questionnaire (left) and the post-test questionnaire (right).*

Figure 4: *Students of the virtual group interacting with the system (left) and students of the traditional group looking at the maps (right).*

As far as concerns the procedure of the experimental setting, the 17 students that participated in the study were randomly assigned to one of two groups: the traditional group (control group) and the virtual group. We should mention that none of the students had ever been taught anything about the walls of Nicosia before. In addition as pointed out in section 3.1, both interventions (traditional class and virtual class) were based on the same learning content and learning objectives. Therefore we can assume that any differences in the learning performance and user experience can be attributed to the different type of classes (i.e. the two different interventions). Before starting the tour, students from both classes completed the questionnaire with demographic information (gender, age and year at school) and the knowledge test, Figure 3 (left). After that the tour began in parallel for the two classes. One researcher was present at each class. The traditional group entered the room with maps. Maps of the walls of Nicosia from different chronological periods are exhibited in this room. The teacher talked to the students about the fortifications showing to them the corresponding information on the maps, Figure 4 (right).

The touch table running the application was set up in a separate room. Students entered the room and a short introduction about the system followed by the researcher. Then the teacher talked to the students about the Walls. The teacher of this tour was interacting with the application while she was talking to the students, and she was showing the corresponding information for the walls on the system, Figure 4 (left).

Teaching in both classes was interactive. The teachers asked students several questions about the walls (e.g. their shape, extend etc). The students were requested to find the answers by studying the maps for the traditional group or by interacting with the system for the virtual tour. The researcher that observed the virtual group noted that it was clear that students were able to answer the teacher's questions easily and in a short time while the researcher that observed the traditional tour stated that students were not able to answer all the questions. In those cases the correct answer was given by the teacher. The session for both classes last about 15 minutes.

	Intervention	N	Mean	Std. Deviation	t	Sig. (2-tailed)
Pre-test knowledge score	Virtual group	8	2,500	0,9258	-2,407	0,029
	Traditional group	9	3,556	0,8819		

Table 1: *Pre-test learning performance differences.*

	Intervention	N	Mean	Std. Deviation	t	Sig. (2-tailed)
Post-test knowledge score	Virtual group	8	8,250	0,7071	2,495	0,032
	Traditional group	9	6,333	2,1794		

Table 2: *Post-test learning performance differences.*

After each session students were given around 20 minutes in order to complete the post-test questionnaire by filling out the Smileyometer and the knowledge test, Figure 3 (right).

4. Data analysis and results

This study investigates a) whether there is a difference in learning performance between the students of the two different groups and b) whether there is a difference in user experience between the students of the two different groups. The answered knowledge tests were scored by counting the number of correct answers given by each student. Regarding the differences in learning performance and for the pre-test phase independent samples T-test was employed in order to compare learning performance between the two classes. Significance level was set at 0.05 for all the analyses performed. T- test analysis revealed statistical significant differences [(t15) =-2.407, p=.029] between the traditional group (M=3.55, SD=0.88) and the virtual group (M=2.5, SD=0.92). This finding shows that traditional group performed significantly higher at the pre-test knowledge questionnaire (Table 1).

For the post-test phase independent samples T-test was employed in order to compare learning performance between the two classes. The analysis revealed statistical significant differences [(t15)=2.371, p=.032] between the traditional group (M=6.33, SD=2.17) and the virtual group (M=8.25, SD=0.70). This finding shows that virtual group performed much higher at the post-test knowledge questionnaire (Table 2).

We further investigated whether the change in learning performance within each group across the pre-test and the post-test phase. Two paired-samples t-test were performed. In both groups there were found significant changes in learning performance (Table 3). In the traditional group there was a significant increase in learning performance from pre-test (M=3.56, SD=0.882) to post-test phase (M=6.33, SD=2.179), t(8)=3.656, p=0.006). Mean increase in learning performance was 2.77. In the virtual group there was a much higher significant increase in learning performance from pre-test (M=2.50, SD=0.926) to post-test phase (M=8.25,

SD=0.707), t(7)=12.689, p=0.000). Mean increase in learning performance was 5.75 (Table 3).

We move on with the analysis of the second research question which is about the user experience. Independent samples T-test was also employed in order to compare user experience between the two classes. The analysis showed statistical significant differences [(t15)=2.800, p=.023] between the traditional group (M=4.22, SD=0.83) and the virtual group (M=5.00, SD=0.0). It is evident that students from both classes reported high levels of user experience, however findings from this analysis shows that virtual group reported user experience at significantly higher levels (Table 4).

In order to control other variables for possible effects on the results, additional test were performed. In more details, we tested whether gender had a significant impact on learning performance and user experience. No statistical significant differences were found for learning performance as for the pre-test [(t15)=0.243, p=0.812] and the post-test [(t15)=-1.912, p=0.075]. No statistical significant differences were found for user experience [(t15)=-0.470, p=0.645].

5. Discussion and conclusions

This study evaluates the use of an interactive 3D virtual world that runs on a multi-touch table. The "Walls of Nicosia" is installed and used in the Leventis Municipal Museum in Nicosia, Cyprus. The main research goal was to investigate whether there are differences in learning performance when interacting with the virtual world and to evaluate user experiences with it. Students from a Nicosia elementary school, aged 10-11 participated in the study. We created two different types of classes (interventions): a traditional one (control group) where students took a guided tour throughout the museum and learned about the walls of Nicosia through printed maps exhibited at the museum and the virtual class where students interacted with the application "The Walls of Nicosia". The two classes were based on the same learning content and learning objectives.

A multiple choice knowledge test was developed in order to assess learning performance and the "Smileyometer" tool was employed in order to evaluate user experience. This

		Mean	N	Std. Deviation	Paired Differences		
					Mean	t	Sig. (2-tailed)
Traditional Group	Pre-test learning performance	3,56	9	0,882	2,77	3,656	0,006
	Post-test learning performance	6,33	9	2,179			
		Mean	N	Std. Deviation	Paired Differences		
					Mean	t	Sig. (2-tailed)
Virtual group	Pre-test learning performance	2,50	8	0,926	5,75	12,689	0,000
	Post-test learning performance	8,25	8	0,707			

Table 3: *Paired-samples t-test for learning performance.*

	Intervention	N	Mean	Std. Deviation	t	Sig. (2-tailed)
User Experience	Virtual group	8	5,00	0,000	2,800	0,023
	Traditional group	9	4,22	0,833		

Table 4: *User experience between the students of the two groups.*

tool has been developed by [Rea08] specifically for assessing user experience when users are children and has been validated in several studies.

Data analyses revealed significant differences in both learning performance and user experience between the students of the two groups. Although students from the traditional group performed better at the pre-test knowledge test, after the completion of the experiment students from virtual group performed much higher in terms of learning on the walls of Nicosia. The use of the virtual world was very effective in terms of learning performance. This contrasts with findings of [WR10] whose evaluation of E-Junior did not reveal any statistically significant differences in learning performance between the traditional and virtual group in their study. The superiority of the virtual world application in terms of learning effectiveness is confirmed though by other studies, which investigate similar technologies (such as games, 3D virtual worlds, etc.) [KG07] [Pap09]. Moreover no significant gender differences were found on learning performance and user experience, which is confirmed by some studies [KG07] [Pap09] and contrasts the findings of other studies [JUKY99] [YU99].

In addition students from the virtual group were thrilled with their experience, which has been rated at significantly higher levels. They were active, raising their own questions to the teacher, while the students of the traditional group were passively listening to the teacher. Students from the virtual group seemed more enthusiastic, engaged and they expressed a greater intention to visit the museum and use the "Walls of Nicosia" again. Such findings are confirmed by other studies as well [WR10] and they are considered as crucial for the enhancement of the learning process. This has greater implications for museum contemporary technologies whose learning aspect is very strong and a critical success factor.

This study has also some limitations. One certain limita-

tion is the knowledge test we created which was quite short and focused on factual knowledge and short-term retention. In a future study a longer-term retention of knowledge and other types of knowledge (other than simple concepts and mere facts) can be evaluated. In addition a future study can investigate the association between motivation to learn aspects and user experience. Another important issue that a future study can pursue is the deeper investigation of the impact that individual learner characteristics (such as specific learning and cognitive styles) may have.

In conclusion, this study demonstrated that systems such as 3D virtual worlds, multi-touch interactive tables and so on, can provide a great user experience to the visitors of museums (in this case children), to further motivate them and help them at the same time to entertain themselves and learn effectively.

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References

[AC09] AVERKIOU M., CHRYSANTHOU Y.: Evaluating a multi-touch interface for 3d navigation inside the virtual world of a museum exhibit. In *VAST2009* (2009). 1, 2

[AW06] ANG K., WANG Q.: A case study of engaging primary school students in learning science by using active worlds. In *Proceedings of the First International LAMS Conference 2006: Designing the Future of Learning* (2006), pp. 5–14. 1

[BH05] BENNETT J., HODGES A.: The Development of Science Museum WebSites: Case Studies. *E-learning and virtual science centers* (2005), 366. 1

[CIR04] CHITTARO L., IERONUTTI L., RANON R.: Navigating 3d virtual environments by following embodied agents: a proposal and its informal evaluation on a virtual museum application. *PsychNology Journal (Special issue on Human-Computer Interaction 2* (2004), 24–42. 1

[GCR01] GAITATZES A., CHRISTOPOULOS D., ROUSSOU M.: Reviving the past: cultural heritage meets virtual reality. In *VAST '01: Proceedings of the 2001 conference on Virtual reality, archeology, and cultural heritage* (New York, NY, USA, 2001), ACM, pp. 103–110. 1

[Gel06] GELLER T.: Interactive tabletop exhibits in museums and galleries. *IEEE Comput. Graph. Appl. 26*, 5 (2006), 6–11. 1

[Hut07] HUT P.: Virtual laboratories. In *Progress of Theoretical Physics* (2007), vol. 164, pp. 38–53. 1

[JUKY99] JEAN J. D., UPITIS R., KOCH C., YOUNG J.: The story of phoenix quest: how girls respond to a prototype language and mathematics computer game. *Gender and Education 11*, 2 (1999), 207–223. 6

[KAC08] KUNKEL T., AVERKIOU M., CHRYSANTHOU Y.: A web-based virtual museum application. In *Proceedings of the 14th International Conference on Virtual Systems and Multimedia* (October 2008), pp. 275–277. 1

[KG07] KE F., GRABOWSKI B.: Game playing for maths learning: Cooperative or not? *British Journal of Educational Technology 38*, 2 (2007), 249–259. 6

[KSW06] KAROULIS A., SYLAIOU S., WHITE M.: Usability evaluation of a virtual museum interface. *Informatica 17*, 3 (2006), 363–380. 1

[LTF*04] LOSCOS C., TECCHIA F., FRISOLI A., CARROZZINO M., WIDENFELD H. R., SWAPP D., BERGAMASCO M.: The museum of pure form: touching real statues in an immersive virtual museum. In *VAST* (2004), pp. 271–279. 1

[Nij00] NIJHOLT A.: Agent-supported cooperative learning environments. In *International Workshop on Advanced Learning Technologies (IWALT 2000)* (Los Alamitos, USA, December 2000), Kinshuk I., Jesshope C., Okamoto T., (Eds.), IEEE Computer Society Press, pp. 17–18. 1

[Pap09] PAPASTERGIOU M.: Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation. *Computers and Education 52*, 1 (2009), 1 – 12. 6

[PCS*08] PATIAS P., CHRYSANTHOU Y., SYLAIOU S., GEORGIADIS C., D. M., S. S.: The development of an e-museum for contemporary arts. In *VSMM* (2008). 1

[Rea08] READ J. C.: Validating the fun toolkit: an instrument for measuring children's opinions of technology. *Cogn. Technol. Work 10*, 2 (2008), 119–128. 3, 5

[Rou01] ROUSSOU M.: Immersive interactive virtual reality in the museum. In *in In Proc.of TiLE (Trends in Leisure Entertainment* (2001). 1

[TVZ*05] TZANAVARI A., VOGIATZIS D., ZEMBYLAS M., RETALIS S., P. L.: Affective aspects of web museums. *Studies in Communication Science, for the Thematic Section "User-Centered Communication Design for Interactive Applications" 5*, 1 (2005). 1

[WR10] WRZESIEN M., RAYA M. A.: Learning in serious virtual worlds: Evaluation of learning effectiveness and appeal to students in the e-junior project. *Computers and Education 55*, 1 (2010), 178 – 187. 6

[WWWC04] WOJCIECHOWSKI R., WALCZAK K., WHITE M., CELLARY W.: Building virtual and augmented reality museum exhibitions. In *Web3D '04: Proceedings of the ninth international conference on 3D Web technology* (New York, NY, USA, 2004), ACM, pp. 135–144. 1

[YU99] YOUNG J., UPITIS R.: The microworld of phoenix quest: social and cognitive considerations. *Education and Information Technologies 4*, 4 (1999), 391–408. 6