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How serious games in cultural heritage are being evaluated

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Abstract

Serious Games (SGs) in the field of Cultural Heritage (CH) aim to enhance cultural awareness and facilitate learning of cultural content while at the same time entertaining. They are being used in latest years among other means in order to communicate tangible and intangible CH and support learning. There is strong evidence that cultural heritage serious games (CHSGs) can effectively facilitate the communication and understanding of cultural content, activate participant's interest and enhance their motivation for further exploration of cultural heritage. The aim of this study is to review how the CHSGs are being evaluated. The findings of the study are expected to be useful for the design, implementation and evaluation of future SGs in the field. The results of the study showed that more rigorous ways of assessment need to be used to collect data for knowledge acquisition and users' perception in both school and museum context.

Keywords: Serious games, cultural heritage, review, evaluation, assessment

Introduction

SGs are the digital games that use entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives (Zyda, 2005), meaning they are used for purposes other than pure entertainment (Susi, Johannesson & Backlund, 2007). The interest and usage of SGs has been aroused in recent years due to the research evidence on the effectiveness that they have in learning and the understanding of various subjects.

Regarding CHSGs, there is an interest that focuses to the enhancement of motivation for cultural heritage exploration whether it is in the context of a history course or an archaeological site/monument/cultural institution visit. CHSGs are being used in latest years among other means such as virtual reality (VR) and augmented reality (AR) applications, virtual tour guides and virtual museums in order to involve museum visitors in cultural heritage processes and familiarize the audience with techniques and attitudes that would maximize their positive disposition during the visit. There is a strong evidence that CHSGs can be effective means to create experiences that bring balance between entertainment and education and at the same time increase the interest for cultural heritage content and motivation for further exploration (Anderson et al., 2010; Mortara et al., 2014b). Yet, there is a lack of systematic approaches to assess and describe the learning outcomes of the games (Paliokas & Sylaiou, 2016). The bottom line of this study is to find ways for more systematic and effective design, implementation and evaluation of CHSGs. The rest of the paper is structured as follows. Next section is the previous work on CHSGs reviews. The second section presents the methodology used for this review study as well as the results that have been analyzed. Finally, the last section presents the conclusions of the study with some suggestions on future work.

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Related work and contribution

Previous studies have analysed various perspectives of CHSGs. The first review in the domain (Anderson et al., 2010), analyses technological aspects of the CHSGs, by classifying the games into prototypes and demonstrations, virtual museums and commercial historical games. Mortara et al. (2014b) in an extensive state-of-the-art review highlight the educational objectives of the games: cultural awareness; historical reconstruction; heritage awareness, along with other factors such as genre, context of use, technology and learning effectiveness. Malegiannaki & Daradoumis (2017) emphasize on the genre and plot related to the CHSGs, while mapping their context of use, number of players and game outcomes. Paliokas & Sylaiou (2016) make an overall mapping of the CHSGs from 2009 to 2015 including their goal, purpose, market, audience and educational outcomes.

This study aims to extent the research that has been conducted in the field, by emphasizing in the evaluation study types that are being used in order to extract the learning outcomes. Along with the evaluation study types, measuring tools, sample and acquisition assessment are being analyzed. Additional aspects of the games are being studied in order to have an overall picture of the games reviewed: goal, context of use, target group, technology. The findings of the study are expected to be useful for the design, implementation and assessment of future CHSGs and contribute to a more concrete knowledge on the ways that the CHSGs are being evaluated. The results of the review can be used as a guidance at all stages of the creation of a game, in order decisions to be taken regarding the intended quality of the research that is going to be conducted; the ways that the game is going to be evaluated and the tools to be used, as well as the ways that major obstacles can be solved or limited, from the very beginning. Finally, this study aspires to encourage future researchers to deeper examine the educational and technological essence of CHSGs.

Methodology

A search was conducted in the IEEEXplore and the Scopus libraries for CHSGs published from 2012 to 2017. The search terms were “Serious game” OR “Digital game-based learning” OR “Edutainment” OR “Educational game” AND “Cultural heritage” OR “History” OR “Museum”. The terms were inserted in the search engines fields according to the available functionalities of the searching tools, having in mind the aforementioned terms logical combination. The search resulted to a total sample of 491 items. By reading the title and/or abstract and/or keywords of the papers, the first selection of games was conducted based on the following inclusion criteria:

1. The research paper should refer to a serious game. Further reading of the papers led to the exclusion of interactive museum installations, informative virtual museums and digital museum guides, that do not have serious game intentions.
2. The serious game should be evaluated. The paper should describe at least one phase of the game assessment. The games that their evaluation has been designed, and described, without being conducted were not included.
3. The serious game should have cultural heritage content, including natural heritage.

Additional, games were found from the existing reviews that have been conducted in the field (Malegiannaki & Daradoumis, 2017; Paliokas & Sylaiou, 2016; Mortara et al. 2014b; Anderson et al. 2010). The games that finally included in this study are being displayed in Table 1.

Results

The games were classified according to their main goal, context of use, target group, the used technology and the evaluation study conducted. More details about the games' assessment process were analyzed regarding the measuring tools and the sample of the study. Finally, it was noted whether the researchers assessed the participants' perceived knowledge, or the knowledge gain itself (Table 1).

Initial classification of the games

The games were classified according to their goal, into *educational*, *technology-oriented* and *museum-oriented*. Twenty out of twenty-four games were classified as educational games that aim to disseminate CH and raise awareness in a specific cultural heritage topic or teach historical content. Other games were technology-oriented that aim to deliver some information about CH and give emphasis in using innovative and attractive interaction ways rather than on educational impact of the game (Admotum & Holoint, Imago Bononiae, Kunyu Quantu). As museum – oriented was classified one of the studied games (MuseUs).

Games were classified as *cultural visit* and *classroom setting* according to their context of use. The first category consists mainly of games that are intended to be played during a visit to a cultural institution having thirteen in a museum and one in a library (A Virtual Laboratory). One game is set to an exhibition (Imago Bononiae), and another to the historical places of a city center (The Mystery of Elin). The second category refers to the games that are intended to be used in formal education, in the context of a course, and consists of six games (Roma Nova, P&Q of the Sanctuary, M-Histoty, The Plague, An-Ping, Analects of Confucius). In a generic cultural heritage context are classified the remaining two games, while they are not related to specific context of use, and they can potentially be used in any setting (TiE, Icura). All of the classroom games have historical content (five of them integrated in history course and one of the to the Chinese philosophy (Analects of Confucius).

The target of the games is the *general audience*, *children, teenagers*, *young adults* and *adults*. The general audience is the target of nine games. Both the games with the generic use (TiE, Icura) belong to this category, while the rest seven games are museum games (Admotum & Holoint, Imago Bononiae, Fishbourne Palace, Hippocratica Civitas, The Seafarers, Taslihan, Virtual dive). Eleven of the games target to children whether they are in elementary school or middle school age (five cultural visit and six classroom games). The classroom games of this category target to young children ranging from age 6 to 14 with common age range 10 - 11. The cultural visit games target to age range from 7 to 14, with common age range 11 -12. The common age range for classroom and cultural visit games is 11. Lesser games can find a child to play at the age of 10 or 12, in 9, 8, 13, and so on. The rest four games are in the context of a cultural visit. QuesTInSitu targets to children and young teenagers. Gossip at Palace targets to teenagers, while MuseUs at teenagers and young adults, and the Virtual Laboratory at young adults and adults.

The games are played in PC, mobile devices, VR systems or projection-based systems. Six of the mobile applications are location-based with one being outdoor activity (The Mystery of Elin). Four of the games use markers to trigger AR content (Intrigue at the museum, Gossip at palace, MuseUs, Fishbourne Palace), in indoor activities. Three of the games use VR systems with headset to enhance immersion such us Oculus rift headset (A Virtual Laboratory, Hippocratica Civitas, Virtual dive) and one with projection-based stereoscopic VR system (The Battle of Thermopylae). Four other games used a projection-based system (C-OLiVE, Admotum & Holoint, Imago Bononiae, Kunyu Quantu). Three of the projection systems are

gestured-based with the use of sensors like Kinect and Leap Motion. In Kunyu Quantu installation there is also voice interaction. The latest, gestured based systems are used in the games that are technology-oriented, in a cultural visit context. Although, such installations do not have much education impact, they do have educational potentials. Additionally, as attractions of the exhibitions, trigger visitors' attention, who can play immediately in the natural flow of the exhibition visit.

Evaluation of cultural heritage serious games

The games studied were classified according to their evaluation study type (Petri & von Wangenheim, 2017). The researchers used *experimental study*, *non-experimental*, *quasi-experimental*, or they conducted the study in an *ad-hoc* manner. Roma Nova game during an initial evaluation was assessed ad-hoc. The researchers used direct questions to the participants to collect preliminary data. Most of the games (twenty-one) were evaluated with non-experimental process, where data about the users' experience and knowledge acquisition gathered with a more systematic way, although without the use of a comparison/control group. These data mainly collected through questionnaires and/or semi-structured interviews.

Three of the non-experimental studies used pre and post- tests to compare the outcomes of their intervention (P&Q of the Sanctuary, Icura, The Plague) while the other studies used only post – tests (eighteen). These pre and post studies used questionnaires to evaluate: participants' knowledge gained before and after the game (P&Q of the Sanctuary, Icura, The Plague); participants' perceptions about the game and game experience (Icura, The Plague), as well as users' motivation on visiting an archaeological site. Mortara et al. (2014a) suggested that questions for knowledge acquisition to be different before and after the game in order to avoid the selective attention bias. In this case, pre-test questions were used to identify each participants' avg knowledge on the Japanese culture. This process allowed researchers to study the higher-order knowledge acquisition and not to limit the study to the remembering information level. Although, there was not a direct comparison between the outcomes of the pre and post-test, due to the different questions included, participants, especially those with lower previous knowledge in Japanese culture, showed a statistically higher familiarity with higher scores in the topic after the session. The Plague game (Earp et al., 2015) inspired by Design-based research, used additional to the knowledge acquisition test, a joint mind mapping activity and a brainstorming activity. During mind mapping the researchers gathered the collective pre-existing students' knowledge and after the session noted students' changes. During a post brainstorming activity, students asked to design the game according to their preferences, based on some guidelines.

The non-experimental studies with only post-tests ran questionnaires, semi-structured interviews, observations, log data and recordings to collect data. Three studies used questionnaires to gather data on knowledge acquisition/perception and the game experience (TiE, MuseUs, The Seafarers). Two of the studies combined questionnaires, observations and interviews (A Virtual Laboratory, Virtual dive). Interviews based on questionnaires conducted by nine studies (The Battle of Thermopylae, M-History, The Mystery of Elin, Gossip at Palace, Admotum & Holoint, Imago Bononiae, Fishbourne Palace) in combination with observation (The Battle of Thermopylae) or questionnaires (M-History, The Mystery of Elin). Log data about the users' behavior inside the game were gathered in two studies (Gossip at palace, Admotum & Holoint). A systematical observation conducted for a location-based game inside the museum (Intrigue at the museum), where the aim was the users to play the game without being distracted from the real exhibits, in combination with questionnaires

and conversations. Notes about the behavior were kept during another location-based game (QuesTInSitu) were the goal was to investigate the social behavior among the member groups, in combination with questionnaire about knowledge acquisition and perception about the game.

One of the games tested with quasi-experimental study type (Analects of Confucious). Although comparison groups were used, the participants' assignment were nonrandom. Finally, one of the games was assessed with experimental study (C-OLiVE), where three groups were created with the participants randomly assigned to each group. Pre and post questionnaires were used about knowledge acquisition and perception about the game experience and social presence. Regarding knowledge acquisition, the students, filling the questionnaire, had to answer questions not only by recalling information. They had to show higher cognitive level by combining information and indicating their understanding on the collaborative tasks they performed.

The number of studies that conducted evaluation with sample up to 20 participants were eight (TiE, Roma Nova, The Battle of Thermopylae, M-History, Kunyu Quantu, A Virtual Laboratory, The Seafarers, Taslihan), while four of them were tested in early stage in the lab (TiE, Roma Nova, The Seafarers, Taslihan). Nine studies included sample between 21 and 50 participants (P&Q of the Sanctuary, MuseUs, Icura, C-OLiVE, Gossip at Palace, Imago Bononiae, The Plague, Fishbourne Palace, Analects of Confucius), while five included up to 100 participants (Intrigue at the museum, Icura, The Mystery of Elin, QuesTInSitu, Hippocratica Civitas). Two games (Virtual dive, An-Ping) collected participants above 100 with 101 and 153 participants respectively. Admotum & Holoint installation gathered data by 856 recordings, additional to the 30 questionnaires.

The knowledge assessment classified into *knowledge acquisition*, meaning the direct evaluation of the knowledge gain, and the *perceived knowledge*, meaning the participants' perceptions about the knowledge gain that acquired with the game. Eleven games were tested regarding the knowledge acquisition though questions that users had to answer. In some cases, only post-knowledge acquisition was measured, either with a questionnaire on the content of the game (TiE, The Battle of Thermopylae, Hippocratica Civitas, The Seafarers) or on the exact questions that the users had previously answered in the game (QuesTInSitu). In some cases a pre-test was conducted before the game session, with the same knowledge questions being answered by the users after the game (P&Q of the Sanctuary, C-OLiVE). One study used different questions in pre and post-test in order to avoid selective attention bias (Icura). In two games, knowledge acquisition data gathered during semi-structured interviews after the game session with open ended questions, asking the participants to recall the story of the game (The Mystery of Elin) or historical information (Gossip at Palace). During the assessment of Gossip at Palace there were signs that some of the participants did not felt confident with the new knowledge enough to share it, while when the researchers tried to encourage children to express freely about a museum object, they reacted positively and could recall details that may have not been expressed in a different context (Rubino et al., 2015).

One study evaluated participants' perception on whether they gained knowledge during the game session (MuseUs) with 5 point Likert scale questions, while in another study perceived knowledge and acquisition were measured both (Analects of Confucius). A few studies did not evaluate knowledge acquisition or perception or it is not clear how knowledge was measured (Table 1).

Table 1. Evaluation of CHSGs

	SG	Ref.	Evaluation study type	Tools	N	Know ledge
1	TiE	Bellotti et al., 2012	Non-exp.	Post quest.	9	Acq.
2	Roma Nova	Vourvopoulos et al., 2012	Ad-hoc	Direct questions	5	-
3	The Battle of Thermopylae	Christopoulos et al., 2013	Non-exp.	Post semi-structured int., observation	12	Acq.
4	Puzzle and Quiz of the Sanctuary	Antoniou et al., 2013	Non-exp.	Pre & post quest.	26	Acq.
5	MuseUs	Coenen et al., 2013	Non-exp.	Post quest.	21	Perc.
6	Icura	Mortara et al., 2014a	Non-exp.	Pre & post quest.	61	Acq.
7	M-History	Lee et al., 2014	Non-exp.	Quest., semi-structured interviews	13	-
8	Intrigue at the museum	Xhembulla et al., 2014	Non-exp.	observations, conversations, quest.	30, 81	-
9	C-OLiVE	Apostolellis & Bowman, 2014	Exper.	Pre & post quest., video recordings, log data	47	Acq.
10	The Mystery of Elin	Diaz et al., 2014	Non-exp.	Post quest., semi-structured interview, systematic observation	82	Acq.
11	Gossip at palace	Rubino et al., 2015	Non-exp.	Quest., semi-structured interviews, log data	37	Acq.
12	Admotum & Holoint	Fanini et al., 2015	Non-exp.	Scenario-driven interviews, log data, recordings	30, 856	-
13	Imago Bononiae	Fanini & Pagano, 2015	Non-exp.	Scenario-driven interviews	30	-
14	Kunyu Quantu Wold Map game	Peng et al., 2015	Non-exp.	Focus groups – interviews	5	Perc. (3rd person)
15	The Plague	Earp et al., 2015	Non-exp.	pre & post quest., joint mind map, brainstorming activity	35	Acq.
16	A virtual laboratory	Lorenzini et al., 2015	Non-exp.	Quest., observations, interviews	14	-
17	Fishbourne Palace AR	Sylaiou et al., 2015	Non-exp.	Interviews with structured quest.	29	-
18	QuesTInSitu	Melero et al., 2015	Quasi-exp.	Observation, post quest.	76	Acq.
19	Hippocratica Civitas	Andreoli et al., 2017	Non-exp	Post quest.	72	Acq.
20	The Seafarers	Philbin-Briscoe et al., 2017	Non-exp.	Quest.	9, 15	Acq.
21	An-Ping game	Shiue & Hsu, 2017	Non-exp.	Quest.	153	-
22	Taslihan SG	Rizvić, 2017	Non-exp.	Quest., interviews	9, 7	-
23	Analects of Confucius	Sung et al., 2017	Quasi-exp.	Pre & post quest.	49	Perc./ Acq.
24	Virtual dive	Bruno et al, 2017	Non-exp.	post-test quest., observation, interviews	101	-

Conclusions

A review study was conducted on the CHSGs by indicating the ways that they are being evaluated after capturing their basic aspects. The results showed that most of the studies

conducted non-experimental methods with one intervention group and lack of comparison group, making difficult to draw conclusions about what would happen without the game session. Most of the non-experimental studies did not use a pre-test in order to compare the intervention group before and after the session. Most studies ran questionnaires or semi-structured interviews and only two utilized the ability to observe players' behavior through log data. The sample of the participants were small in most cases. The lack of experimental studies; the lack of pre-tests in non-experimental studies; the small number of samples; raise thoughts about the validity of the outcomes. Although, CHSGs' goal is learning along with entertainment, many studies did not assess the knowledge acquisition. On the contrary, two studies evaluated the participants' knowledge in higher cognitive level, and not only in information retention, while one study assessed both knowledge acquisition and users' perception about their knowledge gain. It is evident that more rigorous methods of evaluation need to be used in CHSGs, while there are individual bright examples that can inspire future research in the field. CHSGs have a wide range of application, with different research fields involved in the process. The rigorous assessment of knowledge acquisition in such various contexts and use cases, is not an easy task, and requires the collaboration of various disciplines. Future, studies may contribute to the field by analyzing the aspects that are being measured regarding the learning outcomes.

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