Article

Game-Based Learning in Museums—Cultural Heritage Applications

Marijana Ćosović [1],*,† and Belma Ramić Brkić [2],*,†

[1]   Faculty of Electrical Engineering, University of East Sarajevo, 71123 East Sarajevo, Bosnia and Herzegovina
[2]   Faculty of Computer Science, University Sarajevo School of Science and Technology,
     71000 Sarajevo, Bosnia and Herzegovina
*   Correspondence: marijana.cosovic@etf.ues.rs.ba (M.Ć.); belma.ramic@ssst.edu.ba (B.R.B.)
†   These authors contributed equally to this work.

check for
updates

Abstract: As traditional museums migrate to the virtual world, they offer wider access to the exhibit collections but often fail to present content of those collections in more engaging way. Game-based learning is one of the solutions to mitigate this inevitable transition and support active learning in the process. It is increasingly gaining interest from the cultural heritage scientific community for the purpose of promoting cultural heritage, raising awareness of its importance and motivating users to visit cultural institutions such as museums more often. There are numerous examples of serious games that are based on or contain heritage content. Tangible cultural heritage is more represented in the virtual worlds and mainly based on applications of 3D technology. Recently, intangible cultural heritage is gaining more visibility within cultural heritage scope as a domain in which game-based learning could assist in its preservation. This paper attempts to address pros and cons of game-based learning in general and reflect on the choices of using serious games in the museum environment.

Keywords: cultural heritage; digitalization; gamification; museums

1. Introduction

With the rapid development of technology and its integration into all spheres of our lives, we need to consider its application and its greater use for the promotion of cultural heritage which has not remained unaffected. We are witnessing the digitization of a large number of museums, their exhibitions, all for the purpose of promoting and attracting visitors [1]. Furthermore, many museums currently offer "in-gallery or portable digital installations via mobile devices" [2]. The challenge remains how to combine virtual content with a real exhibit, or how to animate users after they view a virtual exhibit, to indeed visit the museum.

Cultural heritage applications usually consist of stories, interactive virtual environments and 3D models. Users can explore around the virtual environment, focus on specific artefact, listen to stories, play games, and similar. Very often visitors find themselves in a position where they have to decide where to focus their attention, because the ultimate aim of virtual visits is to enhance the user experience and interest in particular works of art. In addition, serious game designers in cultural heritage domain have to take into account end user's perspective in interpreting digital heritage. There are attempts within the research community on incorporating cultural information into virtual environments, so heritage significance comes to the foresight. There are several frameworks [3,4] devised to guide virtual environment designers when designing for cultural learning; hence, game-based designers could benefit from this knowledge as well. Authors in [5] use multidisciplinary team to exemplify importance of cultural heritage interpretation in the interactive digital storytelling (IDS) application.

The process of learning in the full swing of the digital age has taken on different forms in comparison to the non-digital age. In general, learning encompasses problem solving, decision making and critical thinking. Playing could enhance learning and challenge creativity through imagination, exploration and collaboration. Digital age learners (DAL), observed in [6], have experienced cognitive style changes manifested as parallel versus linear processing of the information, preferring graphical over textual context, accessing information randomly versus incrementally, and prefer twitch speed over conventional speed. Their sense of connectedness is prevailing over acting alone, activity mode is preferred over passive one and they are often willing to put priority on exploring of play and fantasy in contrast to work and reality. DALs view technology as integral part of their life. While keeping all the aforementioned in mind, preserving cultural heritage would eventually depend on DAL generation as they would be the ones to bear the transfer of knowledge to future generations.

Plass et al. [7] find that the combination of cognitive, motivational, affective and sociocultural perspective is necessary when designing serious games for learning. Arguments based on which such games are considered effective learning platform according to the same authors encompasses player motivation, engagement, adaptivity and graceful failure. Although substantial research is present in the fields of training and education, cultural heritage domain could benefit from studies related to evidence of long-term learning as oppose to short-term entertaining aspect of serious games. In order to produce evidence of the value that particular serious game has on learners we need comprehensive evaluation studies. Hamari et al. examine the effectiveness of game-based systems by creating unified framework in which empirical evidence for arguments supporting learning process via serious games varies greatly [8]. Oprins et al. [9] propose a practical model also to examine the effectiveness of serious games and their practicality. Authors use methodology that can be applied to different audiences, tasks and domains hence attempting to create generic framework for serious game assessment.

The most simple and obvious yet most powerful reason to bring serious games into museums is to motivate and engage the visitors of the museums in learning new material through amusing and informative activities. One of the ways in which this could be realized would be looking at potential visitors age group and assessing the benefits and detriment of each age group. For example, digital games, when introduced into elementary school classrooms, have shown to be a great motivator for learning especially amongst boys [10]. Furthermore, Beavis et al. did a pilot study with the educational game "The Voyage" to see if "curriculum-focused museum programs that synthesize game-playing with on-site experiences" encourage education and knowledge acquisition. Initial teacher feedback was very positive and supportive of the research direction [11]. On the other hand, use of digital games as a tool for health improvements in elderly population [12] has proven to have beneficial effects especially on their cognitive health although seniors might show lack of initial motivation in performing such tasks.

Both tangible and intangible cultural heritage are subject to various safeguarding conventions, and the recent focus on intangible cultural heritage has been one of UNESCO's priorities. This is an attempt to preserve cultural diversity in the cultural domain affected by globalization. Furthermore, European Union has funded a number of research projects related to virtual museum such as MU.S.EU.M [13], V-MUST.NET [14], i-MARECULTURE [15], ViMM (http://www.vi-mm.eu) and similar. The aim is to create a network of Virtual Museums that are "educational, enjoyable, long-lasting and easy to maintain" [16].

Game-based learning and in general, serious games, represent an attempt in contributing to the preservation of both tangible and intangible cultural heritage by raising awareness of its importance. They are an attempt to bring cultural heritage closer to a younger user population through interesting, interactive and educational content. One of the ways in which we promote cultural versatility is by employing modern technologies in cultural heritage domain. By exposing younger generations to cultural heritage through a familiar medium, we are attempting its preservation. Hence, survival of cultural heritage relies on, amongst others, the very same technology that affected globalization and initiated a loss of cultural individualism through group identity creation. We do not argue that

technology will replace the human interaction but rather it can assist with transfer of knowledge in cultural heritage domain.

Authors in [17] recognize the importance of serious games usage for preservation of intangible cultural heritage. They differentiate three categories as shown in Figure 1, namely, cultural awareness, historical reconstruction and heritage awareness and they assess available serious games in those domains as well as their educational objectives. In addition to knowledge behind traditional skills, cultural awareness category encompasses oral traditions and expressions as well as habits related to nature and world in general. Various ancient cultures are explored through serious games [17] and allowed users to observe their influence on the contemporary cultures or simply be aware of the historical events, processes, or even entire periods in human history. In addition, users could explore contemporary cultures prior to travelling by means of serious games whether that be related to architectural or natural environment. Depending on a design of serious game it could provide future traveller virtual exposure to chosen culture enriched with plethora of cultural tasks such as language, music, dance, religious ceremonies, customs, and similar. Considering constant advancement in the technology both entertainment and serious games are becoming more powerful and appealing to consumers, with one major difference being that serious game industry has emerged as vision to use technology and activities contained in entertainment games and apply it to non-entertainment fields.
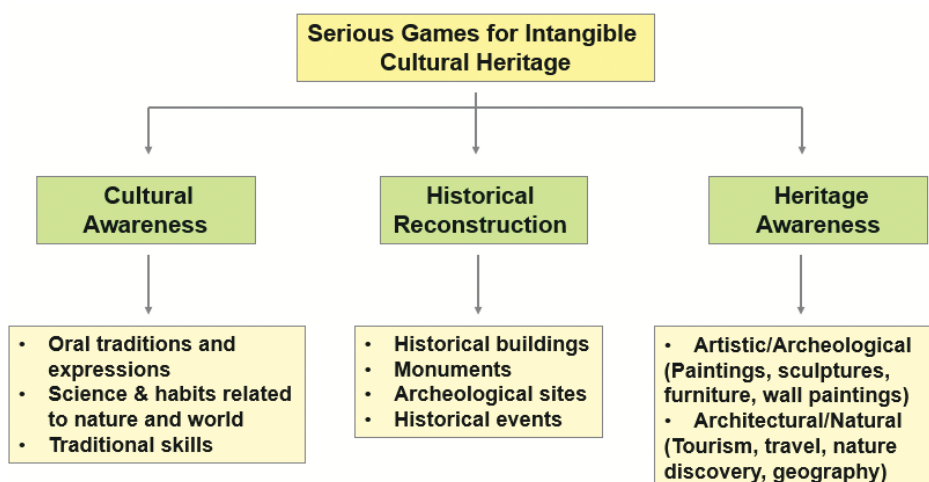

Figure 1. Categorization of serious games' domains.

Visual versus text presentation of the new content is well researched subject with visual education being more powerful as well as allowing learners to accomplish learning goals in shorter time. Application of game-based learning in museum environment is gaining visibility within research community and their cumulative attempts are on the rise through diverse implementations. Goal of this paper is to systematically present advantages and disadvantages of game-based learning in general and find proof within game-based learning examples already implemented in the museums.

2. Pros—Game-Based Learning (Digital Content)

A growing body of research is looking at integrating cultural heritage content into game-based learning due to the proven positive effects of games on learning [18–21]. The pillars of game-based learning are safe practice, experimental learning and interaction. User is engaged in a stimulating environment and rewarded for the accomplishment. According to Buckland and Hendrix, "a game's purpose may be formulated by the user or by the game's designer" [22]. Paliokas et al. [23] believe that serious games can "link directly the museum content with target user groups and fulfil their educational needs" because they are designed to "complement, enhance, or augment the museum experience". Furthermore, gamified learning environments are identified as the most popular approach

in servicing museum visitors where technology is seen as an "attractive and effective medium to interpret solid knowledge into pleasure information [23].

There are numerous research reports exploring the development, implementation and evaluation of cultural heritage serious games [17,23–29]. Furthermore, Schaller makes specific recommendations for designing games for museums, an approach applicable to any culture heritage application [28]. Hanes et al. show the model to be used in presenting heritage content within serious and commercial games [30]. The authors illustrate possible design parameters of how "the heritage instructional content can be manifested within the game". In the later work [31], same authors propose a novel methodology possibly useful to educators enhancing existing video games based on heritage content as well as serious game designers in cultural heritage domain. According to presented methodology authors use activity theory (historical activity context) to guide the design of serious games, based on pre-defined heritage instructional content.

Analysing relevant literature, peer-reviewed articles, research studies and their findings, we identified the following as positives of game-based learning in museums: motivation and engagement, team work, instant feedback and creativity enhancement. Therefore, they will be discussed in more detail in the following sections through the examples available. In addition, pros of game-based learning discussed in following subsections are observed and categorized according to specific aspects (facilitating factors) presented in Table 1.

Table 1. Categorization of positive aspects and facilitating factors of game-based learning.

Pros:	Facilitating Factors:
Motivation and Engagement	Simple vs. complex game design Multi-modality design Cross-platform gaming technologies for building personal exhibits Incentive structures (rewarding mechanism)
Possibility of Team Work	Multi user virtual environment
Progress Assessment	Prompt positive/negative feedback Graceful failure Simultaneous multiple incentive structures Instantaneous/delayed feedback
Creativity Enhancement	Expert team utilization for methodological approach of creative idea production Well defined learning objectives Entertainment appeal

2.1. Motivation and Engagement

According to [32], simple games could motivate visitors in learning process of desired content while more complex mechanics of the games temper motivation through mastering discrete steps leading to the major goal. Design of the game allows for a new point of view in exploring the content of the cultural heritage material presented. Recently, multi-modal approach has been used in serious games design in order to motivate visitors and enhance their experience [33]. For example, a player can inhabit a character of interest while going through a historical process. Game could be designed keeping in mind level of fitness of players hence, integrating physical activity in order to promote movement [34].

The Synthesis virtual museum provides players a possibility of creating their own exhibits using cross-platform gaming technologies [35]. The "Alt-Segeberger Burgerhaus" virtual museum application allows computer based exploration of the exhibits. Using HTC Vive Virtual Reality System, users can immerse into the virtual 3D museum [36]. Users can also build and display their own collections in the Tech Virtual museum by Second life (www.thetechvirtual.org). They are offered two kinds of museums: "the virtual versions of real-life museums and museums completely designed and conceived for Second Life". Furthermore, the Acropolis Museum offers a variety of content through the website (www.theacropolismuseum.gr). During the virtual visit of "Athena, the Goddess of Acropolis", users can "navigate, teleport to points of interest, interact, learn and manipulate the exhibit" [16].

MoMap represents an interactive gamified app for the Athens University Museum of Mineralogy and Petrology that motivates visitors to focus on the details of the exhibits by asking them to collect specific points using the NFC (near field communication) technology [2]. The NFC stickers are positioned next to specific artefacts across the museum to replace physical information labels which are considered as "boring" and "unattractive". Alongside the tour, visitors are prompted to observe the exhibit, collect points and share their experience using devices like smart phones or tablets. Research results show that visitors enjoyed the museum visit using MoMap app because they observed the art work more carefully.

2.2. Possibility of Team Work

Serious games are used and proved to be beneficial for emphasizing teamwork. Application fields vary from education, health, training, management, military etc. Authors in [37] performed extensive case-study in the field of education with nine thousand elementary and high school students from various countries. The study showed that use of serious games based on multi user virtual environments (MUVE) in learning tasks can encourage collaboration even in formal education in which success is still measured as individual accountability in spite the fact that DAL's are collaborating amongst themselves in every other aspect of their existence. Game-based learning has been used in improving collaborative and team work skills in higher education as well [38]. MUVE-based serious games have been used for teaching and practising real (contemporary) sports [39] to teaching traditional sports [40] belonging to intangible cultural heritage and as such are invaluable and a matter of preservation attempts.

Due to globalization, large corporations often have teams dispersed on several location within one country, multiple countries or even continents. In order to have a sense of team amongst the collaborators team building techniques are resourcing to serious games for development of communication and problem-solving skills amongst employees. Hence multi user virtual environments in parallel with serious games are used for virtual team building [41]. The work presented in [17] classifies the games in cultural heritage into mini games that are part of interactive exhibitions used for audience engagement, mobile applications for museum with a reward/engagement mechanism, simulations of historical events, adventures, and role-playing games. Some of the categories, such as mini games, have low learning content, while the Playing history game is due to well-presented and high-volume content implemented in the school system. The multi-player architecture game, whether it be with low or high learning content, allows simultaneous play of several visitors creating a foundation for teamwork [42].

2.3. Progress Assessment—Instant Feedback

Progress assessment of game-based learning is entwined within the game itself and is integral part of it. The intelligent tutoring system [43] is one viable solution. Feedback on player's performance is designed as either positive following success or negative following the failure event and it should be intrinsic and prompt. The term "graceful failure" is emphasized as the learning process does not consist of successes alone but failures as well from which player, upon receipt of adequate feedback, can work on correcting the weaknesses and further improve. Negative feedback can teach consequences of failure in the safe environment (risk free). To provide realistic experience for players negative feedback design should be non-ambiguous. In addition, feedback system could provide suggestive lead in areas of player's weakness.

One practical concern is that feedback system could inadvertently affect the engagement of the player through interruptions. The majority of peer-reviewed papers examined in [8] used points, leader-boards and badges to motivate player moving forward and increase enjoyment and engagement. Multiple incentives are offered to address differences in players' personalities. In case of mini-games feedback is instant and provided after game finishes while for more complex simulation, adventure or role-playing games feedback is realized for the whole duration of the game, spaced according to

the game design. For example, authors in [40] present platform for gamification of traditional sports which offer to the player "visual (two avatars side by side), semantic, textual, and score feedbacks".

The instant feedback across cultural heritage game samples explored for the purpose of this research is visible and appreciated as users lose interest quite quickly for a variety of reasons, which we will explore later. Correctly responding on given game-based challenges is one of the motivating factors for users of all ages to continue exploring the provided virtual content.

2.4. Creativity Enhancement

Design of a serious game is an iterative process that includes experts from, at least, fields of education, art, multimedia, and computer science. In addition, museum environments could use blended learning for enhancement of visitors' creativity by combining curated exhibition with a serious game. Important elements of game design which separate successful games from others are originality and innovation. Producing creative ideas [44] that support structure and guide player's exploration is a must but it is difficult to obtain methodological approach. Clear game goal needs to be specified and multiple paths to success need to be provided. Feedback on progress is necessary so player can adjust his performance if needed. Additionally, and perhaps more importantly, the game should have slight entertainment appeal, even with defined learning objectives as outcomes.

Some of the techniques used for creativity enhancement are brainstorming, negative brainstorming, the insights game, mood boards, random words (random input), storyboarding, metaphorical thinking, mind mapping and brain shifter. There is a strong correlation between the number of ideas produced by employing creative enhancement techniques and number of ideas that develop further [45].

3. Cons—Game-Based Learning (Digital Content)

Although a large number of scientists are researching the impact of technology and its application in education and/or learning, Parette et al. claim that we should move from this question and focus on how to integrate it in childhood education curriculum in a "developmentally appropriate manner" [46]. However, learning by gaming is still not recognized by formal educational systems. This is especially true in low- and middle-income countries. Furthermore, serious games for museums are relatively new concept and little is known about the current trends and use of such applications. They require game mechanics, aesthetics, educational results, and museology features all in one [23]. How much each of these items is represented in the final product may also affect the complexity of the game itself, so it can be either too simple or too complicated [47]. In addition, the games are usually customized and although there are efforts in promoting re-usability it is provided locally whether that is particular game engine offering reusable software objects or various platforms concentrating on user interface objects and templates only [48].

Two examples using similar approach to previously explained MoMap gamified app [2] are the Wolfsoniana Museum (www.wolfsoniana.it/en/index) and the British museum called "British Museum Guide" (www.museumtourguides.com/british-museum-app). The "Wolfsoniana" android application allows visitors to scan NFC tags and quick response code (QR Code) markers to gain more information about the exhibit [49]. At the end of the tour, visitors are also offered to play a knowledge game where they are asked to visually match objects together based on the previously acquired information. With the increased number of experimental studies reporting the positive learning effect of cultural heritage games, it is interesting to note that they "do not provide clear definition of the learning effects and how it is measured" [23].

The British Museum Guide mobile application offers similar interface including "an interactive map of all floors, a virtual walk to the top galleries and high-resolution images of the objects" [2]. Visitors are given an Android tablet to walk around and learn about the exhibits. This is followed by a multiple-choice quiz game with no visual cues. In both of these examples, technology is used as a way

of acquiring more information rather than bringing the visitor closer to the exhibition using a gamified experience.

Virtual museum for the Stoa of Attalos in Athens consists of two separate parts: virtual museum of the exhibits of the Stoa of Attalos and specialized virtual museum of the Stoa "which conveys the information about the wine production and trade routes in the Eastern Mediterranean basin" [16]. Unfortunately, apart from describing the content and interface development, the paper did not present any user evaluation.

Antiniou et al. [26] have identified a gap in methodology for designing games for different spaces of cultural heritage. They reported this process of designing as being "multi-factorial" and "complex". It is for this reason that they are proposing a model for cultural heritage game description and defining three categories of characteristics that can be used: "the game characteristics, the player/visitor characteristics, and the organization characteristics" [26]. The authors believe this model will provide basis for standardizing description of cultural heritage games. However, only one game has been tested, which prevents us from reaching a concrete conclusion about the usability of the offered model.

These are just a few examples of intensive use of virtual content with no concrete results, namely detailed evaluation and follow-up research. Furthermore, some of the cons (identified by analysis of the relevant literature) that we will explore in more detail through examples are: attention span, cost of game and virtual content development, and evaluation of progress through the achievement of set goals.

3.1. Possible Decrease in Attention Span

Attention is a mechanism that determines what part of the scene we focus on and what we ignore [50]. Attention, besides being able to focus our gaze on a particular object, can also narrow our view area or make it wider [51]. Usually, the focussed area is small and if there is a certain movement involved, it is even smaller. In fact, in 1907 Bálint stated that "It is a well-known phenomenon that we do not notice anything happening in our surroundings while being absorbed in the inspection of something; focusing our attention on a certain object may happen to such an extent that we cannot perceive other objects placed in the peripheral parts of our visual field, although the light rays they emit arrive completely at the visual sphere of the cerebral cortex." in [52] and also in [53]. A decrease in attention span represents a common problem in most research studies. Beside physical limitations, there are also limitations with regard to memory and attention overload, since according to [54,55], we can only store up to five different "chunks" of information in visual short-term memory.

Vayanou et al. proposed a storytelling game called "Find the Artwork behind the Story!" where they observed the development of the group experience and explored its demands and affordance [56,57]. The game was designed for groups of visitors who received physical materials such as fabric game boards, post-its and pens. In their subsequent research, the authors designed a mobile game and replaced physical materials with mobile phones that visitors own [58]. Players were given two roles: "Storyteller" and "Voter" and several stages of the game: story making, storytelling, voting, explanations and scoring. Visitors (players) experience interactive live performance in a cultural institution setting. Player focus shifts between the "physical world, the personal mobile screen and the co-players" [58]. They identified that users were most likely to be overwhelmed if too many artworks were introduced simultaneously at the beginning of the game. However, they did not specify the exact number to use as a reference for future studies. Nevertheless, this paper serves as a good starting point in tackling the issue of multiple visits to museums which remains a lasting goal of all cultural heritage institutions.

The serious game "Admotum" was created as part of the 2014 Keys to Rome exhibition held simultaneously in Rome, Alexandria, Amsterdam and Sarajevo, with the aim of presenting the Roman Empire with a combination of museum collections and digital content [59]. The users participated in a treasure hunt involving objects from all four participating museums. All objects are described by storytelling of virtual characters. However, complete immersion of users has not been achieved

because users were so engaged with the not-so-simple gesture-based navigation and therefore failed to convey valuable information about the historical context of the heritage object or site.

3.2. Cost

Storytelling is an important form of information presentation. Facilitating interactive storytelling requires a significant amount of man-hours as well as advanced and adequate equipment of strong processing power. Producing all the content without the user viewing it is a huge waste of time and resources. For example, in the "White Bastian" IDS application [60], users failed to perceive all stories due to their inability to orient themselves in an interactive virtual environment.

It is for this reason that Rizvic et al. have proposed a new IDS method that will include "motivation factor for users to view the whole offered content" [5]. The method was designed by an interdisciplinary team of experts from computer science, visual arts, film directing, literature, psychology, and human computer interaction. These experts offered "concepts, structure and elements which an IDS presentation needs to contain in order to achieve maximum level of user immersion and offer the most satisfactory edutainment experience"[5].

Due to purpose beyond entertainment but stemming from entertainment games, serious games lag in financial and human resource infrastructure to be fair competitor with high-end (dominant) entertainment systems. Although cultural heritage game development is nowhere near as expensive as entertainment games development, one cannot help but wonder if investing more and possibly achieving commercial character, would result in more sound research, increased user knowledge and increased cultural heritage awareness. This is also confirmed by Mortara et al. [17], who claim that since 2000, more attention has been paid to the design and/or beauty of graphic elements because games should look like games rather than "just educational tools with weak game dressing".

3.3. Evaluation of Progress—Translation of Game Progress into Fulfilling Objectives

Each game has some predefined goal and message for the audience. According to Paliokas et al. systematic mapping study results, these messages are grouped as follows: educative, informative, persuasive, and subjective [23]. The distinction between categories depends on "intent criteria and not exclusively on the content of the game". 83.33% of reviewed games are educative/informative, 13.51% persuasive and only 8.11% were considered as subjective.

However, while empathy with the game character and plot might be considered valuable and useful in understanding the broader content of the game, the cultural heritage component, other people's feelings, emotions, and the like, the authors did not offer a methodology for translating this into game-play [17]. The example of empathy can be seen in an *Ngā Mōrehu* first-person shooter (FPS) game from the Te Papa Museum in Wellington, New Zealand where a FPS character cannot be called by the traditional Māori name in school. Instead, the player is shown the following message: "You were born on the dawn of the Māori New Year. Nanny Ira named you after the star cluster Matariki. Miss Marple cannot pronounce your name properly. She calls you Martha anyway." [29]. The intent of the game is to play with emotions and through affective design make the player experience the history of New Zealand. Whether the user experienced the game the way the creators wanted it remains unclear and undefined. Salen and Zimmerman [61] believe that how a game will be perceived ("felt") cannot be controlled. However, the existence of such data could help museums acquire knowledge on how their stated goals are understood by visitors.

4. Conclusions

Due to development of information and communication technology the world's technological capacity to store information sky-rocketed. Cultural heritage domain is represented with small but visible market share. Improvements in data acquisition, storage and analysis allow for large amount of data to be available for researchers in cultural heritage. One of the application fields used in cultural

heritage is game-based learning which although growing is still not widely accepted process. It is, amongst others, used for cultural heritage preservation tasks and has immediate use in museums.

Globalization trends allow for increased mobility and individual exposure to different cultures, and at the same time jeopardizing preservation of its uniqueness. Safeguarding bodies, research community and to a lesser extent entertainment industry are combining their efforts on preserving cultural versatility. UNESCO's "Declaration on responsibilities of present generations towards future generations" states that we all share responsibility to identify, protect and safeguard the tangible and intangible cultural heritage of all humankind by preserving cultural diversity. Development of web technologies allow cultural heritage organizations, such as museums, to have their content available to anyone on-line, in hopes that each museum being a possible point belonging to an interconnected cultural heritage web for future generations of humankind. Such initiative already exists in Europe through projects initiated by EU.

The intangible cultural heritage of the world encompasses huge amount of data that require structure and authentic presentation to the public. In addition, digital-age learners are capable of perceiving information in accordance with proven cognitive style changes, hence game-based learning emerges as a viable solution. The educational benefits have been reported and reflected in visitors' knowledge of the multimedia content presented within museums being an ideal environment for experimenting with unconventional learning.

Although game-based learning has been identified as a successful method for gaining knowledge, it can be concluded from the literature reviewed that each research team works separately, and therefore there are no teamwork results globally. Each research project is based on a specific Museum or part of the exhibit (historical event, specific artefacts, and similar) and the results obtained are not applicable globally or guidelines for such implementation are not visible within the reviewed papers. We need to move away from such research and focus on creating uniform guidelines and methods for game-based learning in museums. Such research will definitely lead to standardization of museum content and a focus on the knowledge, as we currently lack evaluations conducted after attending museum-school educational programs based on video games.

The main contribution of the paper is the identification of the advantages and disadvantages of game-based learning in museums. These have been discussed and analyzed in more detail through the available examples. The main outcomes are presented in Figure 2. It should be noted that, in addition to the above, we identified game logistics as a disadvantage and content differentiation as an advantage, however, due to the lack of specific examples and evaluations, we could not include them in this research because no concrete conclusions or assumptions could be made.

Nevertheless, we presented examples of serious games that have been implemented and tested but have failed to identify a unified framework that could be used for design and development of serious games applied to the cultural heritage domain. In addition, further research is required to explore the real effects of serious games on cultural heritage learning, as to our knowledge no standardize evaluation methods exist. As stated earlier, there exists virtual content in the museums, but we lack evaluation data and consistency. Therefore, further research must change its focus, attempt to group existing methods, offer unified guidelines for the publication and evaluation of museum content. Moreover, post-evaluation analysis will lead us to new insights and open new research domains.

Pros:	Cons:
1. Positive effect of games on learning 2. User engaged in a stimulating environment 3. User rewarded for the accomplishment 4. Games fulfil educational needs 5. Games designed to complement, enhance, or augment the museum experience 6. Users can immerse into the virtual 3D museum 7. Users can build and display their own virtual collections 8. Serious games based on multi use virtual environment (MUVE) in learning tasks can encourage collaboration (team-work)	1. No guidelines on how to integrate games in education curriculum 2. Learning by gaming is still not recognized by formal educational systems 3. Little available knowledge on current trends and use of applications of serious games for museums 4. Lack of game mechanics, aesthetics, educational results, and museology features all in one 5. No clear definition of the learning effects and how it is measured 6. Designing games for different spaces of cultural heritage is considered to be multi-factorial and complex 7. Users overwhelmed if too many artworks are introduced simultaneously – attention span 8. Not-so-simple navigation 9. The cost of developing high-fidelity virtual environments

Figure 2. The summary of the main outcomes.

References

1. Ramic-Brkic, B.; Cosovic, M.; Rizvic, S. Cultural Heritage Digitalization in BiH: State-of-the-Art Review and Future Trends. In Proceedings of the 1st International Workshop on Visual Pattern Extraction and Recognition for Cultural Heritage Understanding Co-Located with 15th Italian Research Conference on Digital Libraries (IRCDL 2019), Pisa, Italy, 30 January 2019; pp. 39–49.

2. Andritsou, G.; Katifori, A.; Kourtis, V.; Ioannidis, Y. Momap-An Interactive Gamified App for the Museum of Mineralogy. In Proceedings of the 2018 10th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Wurzburg, Germany, 5–7 September 2018; pp. 1–4.

3. Ibrahim, N.; Ali, N.M. A Conceptual Framework for Designing Virtual Heritage Environment for Cultural Learning. *J. Comput. Cult. Herit.* **2018**, *11*, 11:1–11:27. doi:10.1145/3117801.

4. Rahaman, H. Digital heritage interpretation: A conceptual framework. *Digit. Creat.* **2018**, *29*, 208–234. doi:10.1080/14626268.2018.1511602.

5. Rizvic, S.; Djapo, N.; Alispahic, F.; Hadzihalilovic, B.; Cengic, F.F.; Imamovic, A.; Okanovic, V.; Boskovic, D. Guidelines for interactive digital storytelling presentations of cultural heritage. In Proceedings of the 2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Athens, Greece, 6–8 September 2017; pp. 253–259.

6. Prensky, M. *Digital Game-Based Learning*; McGraw-Hill Pub. Co.: New York, NY, USA, 2004.

7. Plass, J.; Homer, B.; Kinzer, C. Foundations of Game-Based Learning. *Educ. Psychol.* **2015**, *50*, 258–283. doi:10.1080/00461520.2015.1122533.

8. Hamari, J.; Koivisto, J.; Sarsa, H. Does Gamification Work?—A Literature Review of Empirical Studies on Gamification. In Proceedings of the 2014 47th Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 6–9 January 2014; pp. 3025–3034. doi:10.1109/HICSS.2014.377.

9. Oprins, E.; Visschedijk, G.; Roozeboom, M.B.; Dankbaar, M.; Trooster, W.; Schuit, S.C.E. The Game-based Learning Evaluation Model GEM: Measuring the Effectiveness of Serious Games Using a Standardised Method. *Int. J. Technol. Enhanc. Learn.* **2015**, *7*, 326–345. doi:10.1504/IJTEL.2015.074189.

10. Baek, Y.K. *Gaming for Classroom-Based Learning: Digital Role Playing as a Motivator of Study*; IGI Global: Hershey, PA, USA, 2010.

11. Kelly, L.; Bowan, A. Gamifying the museum: Educational games for learning. In Proceedings of the Museums and the Web Asia, Daejeon & Seoul, Korea, 7–10 October 2014.

12. Nguyen, T.T.H.; Ishmatova, D.; Tapanainen, T.; Liukkonen, T.N.; Katajapuu, N.; Mäkilä, T.; Luimula, M. Impact of Serious Games on Health and Well-being of Elderly: A Systematic Review. In Proceedings of the 50th Hawaii International Conference on System Sciences, Hilton Waikoloa Village, HI, USA, 4–7 January 2017.

13. Euro Innovanet. Beyond the Traditional Museum. In *Character, Profile and Extent of European Virtual Museums*; FMU. S. EU. M. Project: Rome, Italy, 2008.

14. Pescarin, S.; Rizvic, S.; Selimovic, D. V-MUST NET-The Virtual Museum Transnational Network. 2011. Available online: http://www.v-must.net/sites/default/files/SEEDI2011_pescarin-rizvic-selimovic-NCD21047.pdf (accessed on 10 November 2019).

15. Bruno, F.; Lagudi, A.; Ritacco, G.; Agrafiotis, P.; Skarlatos, D.; Čejka, J.; Kouřil, P.; Liarokapis, F.; Philpin-Briscoe, O.; Poullis, C.; et al. Development and integration of digital technologies addressed to raise awareness and access to European underwater cultural heritage. An overview of the H2020 i-MARECULTURE project. In Proceedings of the OCEANS 2017-Aberdeen, Aberdeen, UK, 19–22 June 2017; pp. 1–10.

16. Skamantzari, M.; Kontogianni, G.; Georgopoulos, A.; Kazanis, S. Developing a virtual museum for the Stoa of Attalos. In Proceedings of the 2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Athens, Greece, 6–8 September 2017; pp. 260–263.

17. Mortara, M.; Catalano, C.E.; Bellotti, F.; Fiucci, G.; Houry-Panchetti, M.; Petridis, P. Learning cultural heritage by serious games. *J. Cult. Herit.* **2014**, *15*, 318–325. doi:10.1016/j.culher.2013.04.004.

18. Ding, W.; Marchionini, G. A Study on Video Browsing Strategies. Technical Report. 1998. Available online: https://drum.lib.umd.edu/handle/1903/897 (accessed on 15 November 2019).

19. Goldsmith, T.R.; LeBlanc, L.A. Use of Technology in Interventions for Children with Autism. *J. Early Intensive Behav. Interv.* **2004**, *1*, 166–178.

20. Boucenna, S.; Narzisi, A.; Tilmont, E.; Muratori, F.; Pioggia, G.; Cohen, D.; Chetouani, M. Interactive technologies for autistic children: A review. *Cogn. Comput.* **2014**, *6*, 722–740.

21. Pistoljevic, N.; Hulusic, V. Educational e-book for children with and without developmental disorders. *J. Comput. Educ.* **2018**, 6, 117–141.

22. Backlund, P.; Hendrix, M. Educational games—Are they worth the effort? A literature survey of the effectiveness of serious games. In Proceedings of the 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), Poole, UK , 11–13 September 2013; pp. 1–8.

23. Paliokas, I.; Sylaiou, S. The use of serious games in museum visits and exhibitions: A systematic mapping study. In Proceedings of the 2016 8th International Conference on Games and Virtual Worlds For Serious Applications (VS-GAMES), Barcelona, Spain, 7–9 September 2016; pp. 1–8.

24. Lucey-Roper, M. Discover Babylon: Creating a vivid user experience by exploiting features of video games and uniting museum and library collections. In Proceedings of the Museums and the Web, Albuquerque, NW, USA, 22–25 March 2006.

25. Christopoulos, D.; Mavridis, P.; Andreadis, A.; Karigiannis, J.N. Using Virtual Environments to Tell the Story: "The Battle of Thermopylae". In Proceedings of the 2011 Third International Conference on Games and Virtual Worlds for Serious Applications, Athens, Greece, 4–6 May 2011; pp. 84–91.

26. Antoniou, A.; Lepouras, G.; Bampatzia, S.; Almpanoudi, H. An approach for serious game development for cultural heritage: Case study for an archaeological site and museum. *J. Comput. Cult. Herit. (JOCCH)* **2013**, *6*, 17.

27. Lercari, N.; Onsurez, L.; Schultz, J. Multimodal reconstruction of landscape in serious games for heritage: An insight on the creation of Fort Ross Virtual Warehouse serious game. In Proceedings of the 2013 Digital Heritage International Congress (DigitalHeritage), Marseille, France, 28 October–1 November 2013; Volume 2, pp. 231–238.

28. Schaller, D. Game mechanics and the museum: Designing simple gameplay around complex content. In Proceedings of the MW2014: Museums and the Web 2014, Baltimore, MD, USA, 2–5 April 2014.

29. Kidd, J. Gaming for affect: Museum online games and the embrace of empathy. *J. Curator. Stud.* **2015**, *4*, 414–432.

30. Hanes, L.; Stone, R. A model of heritage content in serious and commercial games. In Proceedings of the 2017 9th International Conference on Virtual Worlds and Games For Serious Applications (VS-Games), Athens, Greece, 6–8 September 2017; pp. 137–140.

31. Hanes, L.; Stone, R. A model of heritage content to support the design and analysis of video games for history education. *J. Comput. Educ.* **2019**, *6*, 587–612. doi:10.1007/s40692-018-0120-2.

32. EDUCAUSE Learning Initiative (ELI). 7 Things You Should Know about Game Based Learning. Available online: https://library.educause.edu/-/media/files/library/2014/3/eli7106-pdf.pdf (accessed on 31 October 2019).

33. Liarokapis, F.; Petridis, P.; Andrews, D.; de Freitas, S. Multimodal serious games technologies for cultural heritage. In *Mixed Reality and Gamification for Cultural Heritage*; Springer: Berlin, Germany, 2017; pp. 371–392.

34. Yim, J.; Graham, T.C.N. Using Games to Increase Exercise Motivation. In Proceedings of the 2007 Conference on Future Play, Toronto, ON, Canada, 15–17 November 2007; ACM: New York, NY, USA, 2007; pp. 166–173. doi:10.1145/1328202.1328232.

35. Kiourt, C.; Koutsoudis, A.; Markantonatou, S.; Pavlidis, G. THE 'SYNTHESIS' VIRTUAL MUSEUM. *Mediterr. Archaeol. Archaeom.* **2016**, *16*, doi:10.5281/zenodo.204961.

36. Kersten, T.P.; Tschirschwitz, F.; Deggim, S. Development of a virtual museum including a 4D presentation of building history in virtual reality. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2017**, *42*, 361.

37. Di Blas, N.; Paolini, P. Multi-user virtual environments fostering collaboration in formal education. *J. Educ. Technol. Soc.* **2014**, *17*, 54–69.

38. Vásquez, S.; Peñafiel, M.; Cevallos, A.; Zaldumbide, J.; Vásquez, D. Impact of Game-Based Learning on Students in Higher Education. In Proceedings of the 9th Annual International Conference on Education and New Learning Technologies (EDULEARN), Barcelona, Spain, 3–5 July 2017; p. 4356.

39. Soltani, P.; Vilas-Boas, J.P. Multi-user virtual environments for physical education and sport training. In *Cases on Immersive Virtual Reality Techniques*; IGI Global: Hershey, PA, USA, 2019; pp. 20–41.

40. Tisserand, Y.; Magnenat-Thalmann, N.; Unzueta, L.; Linaza, M.T.; Ahmadi, A.; O'Connor, N.E.; Zioulis, N.; Zarpalas, D.; Daras, P. Preservation and gamification of traditional sports. In *Mixed Reality and Gamification for Cultural Heritage*; Springer: Berlin, Germany, 2017; pp. 421–446.

41. Bozanta, A.; Kutlu, B.; Nowlan, N.; Shirmohammadi, S. Effects of serious games on perceived team cohesiveness in a multi-user virtual environment. *Comput. Hum. Behav.* **2016**, *59*, 380–388.

42. Klopfer, E.; Perry, J.; Squire, K.; Jan, M.F.; Steinkuehler, C. Mystery at the museum: A collaborative game for museum education. In Proceedings of the 2005 Conference on Computer Support for Collaborative Learning: Learning 2005: The Next 10 Years! International Society of the Learning Sciences, Taipei, Taiwan, 30 May–4 June 2005; pp. 316–320.

43. Hays, M.J.; Lane, H.C.; Auerbach, D. Must Feedback Disrupt Presence in Serious Games? In Proceedings of the AIED Workshops, Memphis, TN, USA, 9–13 July 2013.

44. Dell'Aquila, E.; Marocco, D.; Ponticorvo, M.; Di Ferdinando, A.; Schembri, M.; Miglino, O. *Educational Games for Soft-Skills Training in Digital Environments: New Perspectives*; Springer: Berlin, Germany, 2016.

45. Kultima, A.; Paavilainen, J. Creativity techniques in game design. In Proceedings of the 2007 conference on Future Play, Toronto, ON, Canada, 14–17 November 2007, pp. 243–244.

46. Parette, H.P.; Quesenberry, A.C.; Blum, C. Missing the boat with technology usage in early childhood settings: A 21st century view of developmentally appropriate practice. *Early Child. Educ. J.* **2010**, *37*, 335–343.

47. Sanford, K.; Starr, L.J.; Merkel, L.; Kurki, S.B. Serious games: Video games for good? *E-Learn. Digit. Media* **2015**, *12*, 90–106. doi:10.1177/2042753014558380.

48. Van der Vegt, W.; Westera, W.; Nyamsuren, E.; Georgiev, A.; Ortiz, I.M. RAGE architecture for reusable serious gaming technology components. *Int. J. Comput. Games Technol.* **2016**, *2016*, 3.

49. Ceipidor, U.B.; Medaglia, C.; Volpi, V.; Moroni, A.; Sposato, S.; Carboni, M.; Caridi, A. NFC technology applied to touristic-cultural field: A case study on an Italian museum. In Proceedings of the 2013 5th international workshop on near field communication (NFC), Zurich, Switzerland, 5 February 2013; pp. 1–6.

50. Ramić-Brkić, B. The Influence of Olfaction on the Perception of High-Fidelity Computer Graphics. Ph.D. Thesis, University of Warwick, Coventry, UK, 2012.

51. Posner, M.I.; Petersen, S.E. The attention system of the human brain. *Annu. Rev. Neurosci.* **1990**, *13*, 25–42.

52. Husain, M.; Stein, J. Rezsö Bálint and his most celebrated case. *Arch. Neurol.* **1988**, *45*, 89–93.

53. Simons, D.J.; Chabris, C.F. Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception* **1999**, *28*, 1059–1074.

54. Irwin, D.E.; Andrews, R.V. Integration and accumulation of information across saccadic eye movements. In *Attention and performance XVI: Information Integration in Perception and Communication*; MIT Press: Cambridge, MA, USA, 1996, Volume 16, pp. 125–155.

55. Luck, S.J.; Vogel, E.K. The capacity of visual working memory for features and conjunctions. *Nature* **1997**, *390*, 279.

56. Vayanou, M.; Ioannidis, Y. Storytelling games with art collections: Generic game-play design and preliminary evaluation through game testing sessions. In Proceedings of the 2017 9th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Athens, Greece, 6–8 September 2017; pp. 264–271.

57. Vayanou, M.; Ioannidis, Y.; Loumos, G.; Kargas, A. How to play storytelling games with masterpieces: From art galleries to hybrid board games. *J. Comput. Educ.* **2019**, *6*, 79–116.

58. Vayanou, M.; Loumos, G.; Kargas, A.; Sidiropoulou, O.; Apostolopoulos, K.; Ioannidis, E.; Kakaletris, G.; Ioannidis, Y. Cultural Mobile Games: Designing for 'Many'. In Proceedings of the 2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), Vienna, Austria, 4–6 September 2019; pp. 1–4.

59. Pagano, A.; Armone, G.; De Sanctis, E. Virtual Museums and audience studies: The case of "Keys to Rome" exhibition. In Proceedings of the 2015 Digital Heritage, Granada, Spain, 28 September–2 October 2015; Volume 1, pp. 373–376.

60. Rizvić, S.; Okanović, V.; Prazina, I.; Sadžak, A. 4D virtual reconstruction of white bastion fortress. In Proceedings of the 14th Eurographics Workshop on Graphics and Cultural Heritage. Eurographics Association, Genova, Italy, 5–7 October 2016; pp. 79–82.

61. Salen, K.; Tekinbaş, K.S.; Zimmerman, E. *Rules of Play: Game Design Fundamentals*; MIT Press: Cambridge, MA, USA, 2004.