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Building blocks of the lost past: game engines and inaccessible archaeological sites

Anna M. Kotarba-Morley
University of Oxford, amorley@uow.edu.au

Joe Sarsfield
Nottingham Trent University

Joe Hastings
Nottingham Trent University

John Bradshaw
Nottingham Trent University

Peter N. Fiske
University of Oxford

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Building Blocks of the Lost Past: Game Engines and Inaccessible Archaeological Sites

Anna Maria Kotarba-Morley
University of Oxford, UK

Joe Sarsfield, Joe Hastings, John Bradshaw
Nottingham Trent University and Angry Pirate Productions, UK

Peter Nicholas Fiske
University of Oxford, UK

Abstract:
This paper explores an idea for creating an informal and easily approachable media platform to promote archaeological sites that are inaccessible and lesser known to the public in the form of an educational game. This game will create an illusion of a real archaeological site visit, allowing players direct contact with its environment and surroundings as well as interaction with its ancient and contemporary inhabitants. In an era of international connectivity, globalization, and social networking, it seems appropriate to choose the online computer and mobile gaming industries as media for spreading the interest in heritage and archaeology.

Keywords:
Heritage Education, Public Archaeology, Computer Game, Inaccessible Archaeological Sites, Media in Archaeology

1. Introduction

Games lubricate the body and the mind.

—Benjamin Franklin

The aim of this paper is to explore whether an online educational computer game based on scholarly, detailed, and accurate 3D reconstructions of archaeological sites is a viable medium for displaying those sites which are inaccessible to the public. To this end, this paper will initially focus on reviewing the market for computer games and commenting on current games which are based around historical and archaeological environments. It will continue by discussing the platforms (e.g. PC, console, tablet, smartphone, museum stand) that may be used, whilst assessing their capacities and their potentials for application to different projects. Next, it will discuss the merits of existing game engines for the creation of such games and present frameworks for games which may be applied to different target groups, client needs, and scenarios. It will additionally seek to answer how to provide successful ways of developing games as tools for education through entertainment.

The idea for creating an interactive medium to explore archaeological sites developed from one author's work on a site in an area of the Middle East which is inaccessible to the general public. There, the local environmental conditions would pose additional cost and maintenance challenges for the open-air exposition of the site. Such a site would form a rewarding basis for a case study, although one has not been attempted here in favour of first formulating the principles and methods by which a study would be undertaken. Through discussions and comparative analyses with other sites, it became clear that there is a great need to investigate new media for the displaying and sharing of cultural heritage of all kinds, on the land and under the water (Kalay et al. 2007).

Corresponding author:
anna.kotarba-morley@arch.ox.ac.uk

One of the key rationales for archaeological investigation is to preserve the legacy left to us by previous generations. Another is to make this heritage available to future generations. The computerized, globalized, and networked 21st century obliges us to explore new frontiers in archaeology for the public. Public interest in archaeology is clear and sustained. Film and video game series such as *Indiana Jones* and *Tomb Raider* have left indelible marks on popular culture, becoming key reference points for archaeology in society (Drew 2007).

Nevertheless, traditional displays like those in the older galleries of the British Museum still remain extremely popular, placing this institution at the top of the list of most-visited British tourist attractions every year. The most recently published BM annual review shows that it had 5.7 million visitors, almost 200,000 more than in the previous year (Rickman and Wilson 2010). Despite this influx of visitors, institutions like the British Museum are also seeking new, digital ways of displaying their collections online. For example, the BM's public-access database maintains information on almost 2 million objects and has been visited by over 15 million people for general interest and research purposes. Those numbers show how popular online resources are becoming in teaching and exhibiting cultural heritage, confirming that the internet is rapidly becoming the medium of the future.

Museums today are investing in online games and multimedia displays, such as interactive stands, 3D reconstructions, and holograms of ancient buildings or archaeological objects. Internationally recognized sites, such as the Roman Baths Museum in Bath Spa and the archaeological site of Pompeii, might seem very easy to present to visitors. Their outstanding cultural values and easy site access have already been recognized by UNESCO with World Heritage Site status. Nevertheless, even at such phenomenal monuments, museum managers and exhibition designers are always in search of new methods of making sites more attractive to visitors. Lesser-known, inaccessible, and under-funded sites, however, do not get as much attention. Creating a game based on accurate reconstructions of past environments and peoples would be a rapid and cost-effective way of displaying such sites and making them available to broad groups of new visitors – players.

2. Gaming and Archaeology

There is a large body of games available on the market which relate directly or indirectly to archaeology. These include games which are set in or based on particular historical periods and rely on archaeological and historical information to create the game's environment, such as *Assassin's Creed: Brotherhood* and the *Prince of Persia*, *God of War*, *Total War*, and *Age of Empires* series. They also include games in which the player controls a modern character exploring an ancient environment, such as *Tomb Raider* or *Unchartered*.

Games set in ancient contexts are predominantly strategy games allowing the player, for example, to control an army equipped with contemporary weapons (e.g. *Rome: Total War*, in which the player controls legionnaires, or *Age of Empires II*, in which the player controls a medieval army). These games often inadvertently educate the players in military history, exposing them to landscapes and technologies that existed during particular periods. It is important to note that many of these games are by no means accurate and better serve to raise players' interests in history rather than operate as educational tools *per se*. They also tend to support traditional historical narratives which emphasize the political and military aspects of the past.

Strategy games are most popular with PC gamers. In 2011, 33.6% of all PC games sold were strategy games, in contrast to just 3.8% strategy games sold for console (Gallagher 2011). Strategy games often require complex

controls, and for this reason are not as popular with the console market. Successful examples of these games include the *Total War* games (*Shogun*, *Napoleon*, *Empire, Rome*), *Rise and Fall: Civilizations at War*, and *Sid Meier's Civilization* (*I–V*).

In the series of strategy games called *Sid Meier's Civilization*, players must lead their civilization from antiquity into the future, researching different technologies along the way. In the game, players control armies from different cultural periods. The latest *Civilization* game in the series, *Sid Meier's Civilization V*, was the 5th best seller in 2010 on Steam, a popular online games store, with an estimated gross revenue of $21.9 million (Tassi 2011). It is also currently Amazon's top-selling PC strategy game (followed by *Total War: Rome II*) (Amazon.com 2013), demonstrating that games with archaeological or historical themes are popular and are successful on today's market.

Games set in modern contexts are predominantly adventure games in which the protagonist is an adventurer or archaeologist who is exploring ancient ruins, such as in *Tomb Raider: Unchartered 3*. Other successful examples of these games include the *Total War* series and *Rise and Fall: Civilizations at War*, which are based in several different eras, and games like *Spartan: Total Warrior*, *Dynasty Warriors*, *Prince of Persia*, and *God of War*, which are mainly based in one historical period or in a mythical past. These games are more popular with console players; 29.2% of all console games sold in 2011 were action or adventure games (Gallagher 2011).

Statistics show that the market for these games is extensive, with an expected total consumer spending in the games industry in 2012 of $25.1 billion (Gallagher 2011). The fact that 82% of 8 to 65 year olds in the UK and 68% of American households play computer games (GRABstats.com 2012) shows that the receiving audience is not only significant, but also very diverse. The numbers also show that the average age of a gamer is 30 and that 62% of gamers play with others, either in person or online (Gallagher 2011). These and other statistics also help to target games to particular types of people.

Educational archaeology games for kids are widely available on the market. Some of them are created by museums, such as games and educational media from Birmingham Museum and Art Gallery, *Dirt Detective* by the Museum of Williamsburg, *Londinium* by the Museum of London, *Every Coin Tells a Story* from the Cotswolds Museum, and *Roman Design*, *The Mosaic Game*, and *Across the Board* by the Tyne and Wear Museum. These online games are usually targeted at players aging from 5 to 15 years old and serve not only to educate, but also to develop general interest in the past and encourage direct interaction with archaeological material through museum and site visits.

Some other browser-based games run via services like the BBC, such as *Mummy Maker*, in which players learn how to prepare a mummy; *Dig Deeper Quiz*, an archaeological quiz; *Hunt the Ancestors*, in which players run archaeological prospection, excavations, and buy specialist reports whilst on a limited budget; *Diver's Quest*, in which players dive into the deep to reach a treasure chest whilst answering questions about underwater archaeology; and *Dig It Up: Romans*, in which players move three diggers equipped with a geophysical survey around a field in search of Roman artefacts. These games build archaeological and historical awareness in children and teenagers; however, they are constructed in a way that they can be played just once or twice because the sets of questions and tasks are very limited.

In recent years, there have been several successful recreations of past cultural heritage environments using different game engines (Champion 2011). These range from video fly-throughs of pre-rendered 3D landscapes to

interactive environments, or those accessible for example through the touch screen display (Wang and Champion 2011). Players can walk around and experience sites with their features and objects and immerse themselves in the past environment as if they were a part of it (Champion 2004). Additionally they have an opportunity to explore both, tangible and intangible past – through interaction with e.g. buildings, archaeological features, and landscapes; or through interactions with inhabitants of the past place, their rituals, dances, traditions (Kalay et al. 2007). The game, if successful, becomes 'engaging, challenging, and intuitively usable, and helps create a fantasy world for participants' (Champion 2006).

The *Second Life* engine has been used many times to recreate archaeological and historic sites. At the peak of its popularity, *Second Life* allowed for an exceptional level of interaction and movement through the environment, but the visuals are no longer up to the standards of other game engines. One of the most superb reconstructions in *Second Life* was of Çatalhöyük. Created by UC Berkeley, it won an Open Archaeology Prize (CIO 2007). However popular as it was for its time, the *Second Life* engine is no longer at the cutting edge of gaming technology and has fallen out of fashion. The features of the *Second Life* engine do not match the current generation of game engines. This is why the information for displaying particular sites should be created and curated in such a manner that the raw data can be used in different gaming environments.

Another type of visualization uses point cloud data, usually gathered from laser scanning with an optical remote sensing technology known as Lidar, for fly-throughs or 3D models. The immense level of detail makes it necessary for them to only be presented as pre-rendered fly-throughs, with no user interaction at all, such as the fantastic reconstruction of Musawwarat es-Sufra in Sudan (Rüther 2010). Whilst these are extremely interesting for specialists or amateurs fascinated by a particular site or period, they are not environments which invite visitors to explore them in detail and in multiple visits, unless they are conducting specific research. Nevertheless, they show a value and a potential to be transformed into environments which can be accessed and explored by the general public.

The Portus Project (www.portusproject.org) by the University of Southampton is a great example of a pre-rendered fly-through (Earl et al. 2008; 2009; 2010) showing an accurate, high-detail recreation of the great port of Imperial Rome. The Southampton team used a combination of Google SketchUp, Google Earth, Autodesk 3ds Max, and *Second Life* to create the environment. Project creators used a great mix of previous data from archaeological surveys and excavations, along with detailed library research, to create buildings and environments to scale. Although the environments created serve their purpose as accurate representations, if an environment is to be used for a game or any kind of interactive activities it requires additional details. Those details need to create an illusion of reality and bring a place to life with features such as trees, plants, dirt on the streets, and humans. Modern game engines have tools for creating content like this which can be used to add these details relatively easily. Such as Unreal Engine 3's Instanced Foliage System (Epic Games, Inc. 2012), which allows the developer to select the tree or bush that they want and paint a forest of them straight onto the landscape, automatically rotating and varying the scale to give a realistic feel.

Underwater cultural heritage exhibits an underestimated and underexplored potential for gaming. Oceans and freshwater cover over 70% of the total surface of the earth and the estimates suggest that 3 million shipwrecks still lie on the seafloor. The 2001 UNESCO Convention for Underwater Cultural Heritage stresses that *in situ* preservation is 'the first and preferred option before allowing or engaging in any activities directed at this heritage'. In light

of this recommendation, access to most of the underwater cultural remains will be very limited and usually possible just for visitors with diving certificates. This area of heritage studies is therefore very much in need of further digital and interactive development. As mentioned above, there are numerous games for children and teenagers about underwater heritage; however, high-end strategy or adventure games based on detailed and archaeologically accurate 3D visualizations are not yet available on the market.

In the light of the examples which have been presented, it is clear that a high-end educational adventure or strategy computer game based on accurate reconstructions of archaeological sites is needed. It also shows that it has a great potential in the market to compete with games based on inaccurate or fictional representations of the ancient world.

3. Proposals and Possibilities for an Educational Game Project

This section aims at proposing a framework for developing an educational computer game which could be designed to complement the 3D visualisations of archaeological sites and allow general public exploration of virtual domains. At a later stage, this method could be applied to the development and testing of a case study based on an archaeological site which is inaccessible to the public. The game can also be tailored to different audiences and the users of different devices, however it is envisaged that the target age group will be 15 to 45 years old and the target device will be the PC.

This kind of game should have no winners and each level could be just a subsequent chronological epoch. The reward could simply be to interact with the environment of the next period; this is also the case with a popular recent release, *Journey*. There have even been mods released for some games, such as *The Elder Scrolls: Morrowind*, *Oblivion*, and *The Elder Scrolls V: Skyrim,* which turn off encounters with enemies allowing the player to explore the environment freely with no interruptions. The player could collect and look at artefacts around the environment along the way, giving them a better understanding of the historical environment. Given the subject matter, which is dedicated at a particular target audience, it is less likely that the game will become a blockbuster. Nevertheless, it will allow for archaeological reports, which are sometimes difficult to comprehend for non-specialists, to find their way into the general knowledge.

3.1 Methodology

In the current climate it is possible to have the best of both worlds: there are free game engines available with powerful 3D rendering capabilities. Although they may still not match point cloud data in resolution, with efficient level design and content creation they can provide a very high level of detail. The added benefit is that these game engines can all run in real time, allowing players to interact with the environment as they please and explore it at their own pace (Calef et al. 2002).

3.1.1 Collecting Data Needed for Visualisations

Source data is needed before creation of the game's environment can begin. Many archaeologists long ago saw the usefulness of presenting their sites and findings through 3D visualisations, and those will usually form a perfect environment for a computer game. Additional information can be gathered from photographs, videos, laser scans, point cloud data, excavation reports, maps, technical drawings, and existing historical and comparative information. These methods can also be used to create a 3D model from scratch.

Laser scanning is an extremely useful form of data collection, reproducing existing objects, buildings or entire landscapes in near-perfect detail. Data is collected in the form of a point cloud, a list of millions of points, which when

fed into a 3D development environment can produce a model of extremely high detail and accuracy. As these models have a huge amount of faces, or polygons, they are not suitable for use within a game engine, slowing it down and not allowing for performance in real time. An artist would have to take the scan and break it down into segments in order to recreate the model more efficiently. This process would take a considerable amount of time, but it would still be much faster than creating the same models using only photos or drawings.

Conversion from point cloud to a 3D model that can be used in a 3D development environment, for example Autodesk 3ds Max, consists of four stages: pre-processing, determination of surfaces, polygon generation, and post-processing (Remondino 2003). These actions can be undertaken by use of software such as Pointools or Autodesk AutoCAD. In order to then make the resulting models suitable for use in a game engine, a considerable amount of simplification would have to take place in the post-processing phase. The simplification process (Weyrich 2004) consists of removing a large amount of faces from themodel whilst still keeping a desirable level of aesthetic quality. Having a smaller amount of faces to draw will allow computers to deliver the scene to the screen faster, therefore maintaining high performance (Arnaud 2011) and ultimately allowing the user to experience environments in real-time. Detail removed in the simplification process can be replaced by the creation and application of textures using techniques such as normal or displacement mapping. These techniques give the appearance of a more detailed object, whilst keeping performance costs significantly lower than using the original, highly detailed model.

Once the model has been completed, data from the original scan can be used to create high detail textures, giving the finished model a realistic appearance. This process is extremely useful for recreating sites or artefacts that are complete and undamaged, or where the desired outcome is a 3D representation of a ruin or a damaged object. It is less useful for recreating objects or features currently not available but known from the historical record.

It is important that as many pieces of source data as possible are collected when creating a 3D environment or representation. Relying on one source too heavily may give an inaccurate outcome. Even with a great deal of data available, it can be difficult to achieve a comprehensive understanding of how buildings or objects looked in their original conditions. A certain amount of artistic license may have to be used in order to give these environments a life-like feel if they are to be made into an interactive game environment.

3.1.2 Interactivity

The level of interactivity would vary according to the specific needs of the project. If it is a game destined to be used in a museum stand, then it will require a very different form of interaction from a project meant for a personal computer as a research tool, for education, or for entertainment (Amory et al. 1999). A game designed for a PC or a games console could either be interacted with by use of a keyboard and mouse, or a gamepad. Use of a gamepad, however is preferred over the use of a keyboard and mouse combo, because it is more comfortable for the players.

A project destined for a museum stand would work better with a more immersive level of interaction. Features such as 3D and a motion sensor could be incorporated. The motion sensor could be used to control an on-screen character or navigate menus and interact with data such as graphs and movies. The players could also interact with specific virtual objects, e.g. a piece of pottery, which they can pick up, move around, and learn more about.

A game may also be solely meant for mobile devices such as tablets or smartphones. This could be useful as a data acquisition tool with which professional archaeologists

could acquire information on their mobile or tablet device when working on a site. Such an approach is already used in archaeology, such as at Pompeii. Drawing/CAD tools can be useful on these devices at archaeological sites and unlimited canvas size and huge zoom levels allow for great detail when creating scale drawings' (Wallrodt and Tucker 2011; Tucker and Wallrodt 2013; Wallrodt et al. 2013). Data collected in this way could be transformed further to allow the user visiting a site to see how it looked in a particular period of the past. Tablets rigged with GPS can position the user in a particular point on the surface of the earth and via an online connection with the game engine to display what he sees in front of his eyes, but in the past. This approach has been successfully implemented in Gunnar Liestøl's visualisations for iPad, which he presented at CAA 2012 (Liestøl 2009).

Another possible use for a visualisation on a mobile device could be an as educational game, which is likely to reach a wide audience. With the rise in popularity of smartphones, they have become favoured devices to play games on. The rise in power of smartphones in recent years has also allowed full 3D environments to run on them in real time. Although the performance does not yet match that of games consoles or PCs, a lot can still be achieved on a mobile or tablet device when taking into account the performance limitations during game development.

3.2 A Possible Game Engine

When it comes to creating a game using a 3D visualisation of an archaeological site, an engine is needed to combine all the models and add functionality. Modern game engines also allow for effects, such as real-time lighting. Post-processing adds effects after the game has been rendered, such as depth of field, colour correction, and motion blur. Particle effects simulate real-world effects, such as fire, flowing water, or smoke. Users may interact with the environment through keyboards, mouses, gamepads, motion capture devices such as the Kinect, or combinations thereof.

The three most suitable free and currently available engines are outlined below: Unreal Engine 3, Cryengine 3, and Unity (Table 1). New engines are released frequently by many companies, so only currently available ones with free SDKs (Software Development Kit) will be assessed. Deciding on the correct game engine is an important step in development as each engine has its own strengths and weakness.

Unreal Engine 3 would be the more appropriate engine to accomplish this project. The visual scripting language Kismet and state of the art graphics allow for rapid development of interactive environments and realistic representations of historical sites. The reasonable costing structures make the engine suitable for most financial situations. Although as of this writing Unreal Engine 4 has not yet been released, it is currently in production by Epic Games and a video demonstration of its capabilities was presented to the public in mid-2012. It remains to be seen precisely when the software will be made available and whether it will have a free SDK. Naturally, the latest version of the Unreal development environment available would merit consideration for this or other projects.

3.3 Possible Scenarios

There are many areas within archaeological and heritage projects and institutions where

***Figure 1**. A proposed method for delivering information to users in the game (developed for the purposes of this paper by Angry Pirate Productions).*

Strengths	Weaknesses	Summary
Unreal Engine 3		
• easy to create for multiple platforms at once • supported on most modern smartphone and tablet devices • free to develop for PC + iOS up to $50,000 earnings • powerful and robust engine • social integration using Game Center, posting to Facebook/Twitter walls	• once $50,000 is earned in revenue from a product, 25% goes to Epic Games • slightly outdated graphics • must pay $50,000 for full UE3 license to develop for Android devices	If a project was funded and needed to be produced quickly for multiple platforms, then UE3 would be the best choice. The editor for the engine allows the developer to quickly bring a concept together into a full game and build out for different devices. As long as performance limitations of mobile and tablet devices were taken into account from the start, few changes would have to be made to the product for a PC version or mobile version.
Cryengine 3		
• real time in-game editing • current gen graphics • free to develop for PC if end product is non-profit • give 20% of revenue if end product is profitable	• not supported on mobile or tablet devices • must pay for full licence if end product is made to be profitable	If a project was purely intended as a highly accurate visual representation of an environment, then Cryengine 3 would be the best choice. This is because it has the best graphical rendering capabilities of the three game engines compared.
Unity		
• relatively cheap to develop for PC, iOS and Android • supported on most modern smartphone and tablet devices	• requires 3rd party software for many features such as multiplayer or posting to Facebook and Twitter • outdated graphical capabilities • more difficult to develop with • developers support for engine does not match UE3	If a project had a large time scale and a low budget, then Unity would probably be the best choice. This is because it is relatively cheap to develop for any platform to develop for any platform, in comparison to the other 2 options mentioned; however, it is not as developer friendly or powerful as UE3 or Cryengine 3.

***Table 1**. A comparison of the three game engines under present consideration.*

educational games can be used. The most obvious use of a game would be to recreate a historical site as it would have appeared in its own time. In such a game, the player would be able to navigate around an environment and interact with different areas, buildings, or objects in order to learn more about them.

The player would also be able to explore the fluctuating fortunes of the site, seeing it at war, at peace, in bloom, and in decline. This could be expanded upon by creating storylines, quests, or tasks for the user to play through. This will promote learning as the player would be encouraged to continue playing in order to complete the tasks.

A second scenario in which a heritage game would be useful would be to display a historical site as it appears now. This would be particularly beneficial in museum exhibitions and on-site displays. This would allow players to see and explore the place where the 3D artefacts within the game came from. The exact location and the context of the findings could be indicated to the users giving them an insight into the archaeology behind the exhibit and a greater understanding of the work that archaeologists do (Fig. 1).

A further use would be to create a library of historical objects in which players would be able to select an artefact and be shown relevant information and 3D reconstructions of the

object, much like the inventory in games such as *The Elder Scrolls V: Skyrim* (Fig. 2).

This view would allow users to see the object from all angles and interact with it in a way that would not be possible in a museum or heritage site. One approach would be to have a game with two storylines, one which could be set in antiquity and one in modern times.

The potential player could choose to play one of the available ancient characters, such as a warrior, a priest (Fig. 3), a sales-woman, an artist, a thief, or another created according to the particular specifications of the game. On the other hand, the player could also choose to become a contemporary character, such as a tourist or an archaeologist. This kind of game would be aimed at exploring sites in different periods and through the eyes of their different inhabitants, humanizing them and leading to a better understanding of history by the player. It would also allow for just a simple tour of the site for those players who are not normally interested in gaming. However, for those who always dreamt about being like Indiana Jones, there could be an option of becoming an archaeologist character and taking part in fictional excavations. Below, we present a simple demonstration of how the 3D environment set in an ancient Roman provincial port could look like (Fig. 4). This image is only meant to provide a sample of the technical possibilities; it is not meant to represent a historically accurate reconstruction reflecting any archaeological or scientific evidence.

It would also allow for direct interaction with other online players in the form of a massively multiplayer online role-playing game (MMORPG), all of whom continuously create, re-invent, and populate the site's universe. For example, when building a house, players would be able to acquire the materials with which to build it, source the labour and skill necessary for its construction, and buy or build the furniture to make it a home. The players would be allowed to set their own tasks and,

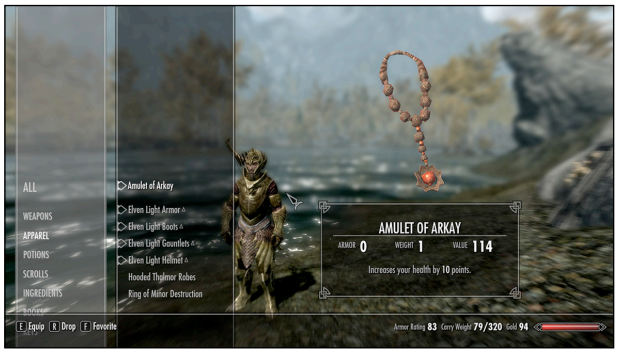

***Figure 2**. An example of the inventory system used in* The Elder Scrolls V: Skyrim.

***Figure 3**. A priest standing at an altar in a demonstration of a 3D simulation (developed for the purposes of this paper by Angry Pirate Productions).*

***Figure 4**. An overview of a town created in order to demonstrate a 3D simulation (developed for the purposes of this paper by Angry Pirate Productions).*

along with their co-players, create and live in an ancient community. The game designers would make sure to pre-set original tasks in a way to keep the players motivated to continue and explore new levels. Some statistics report that the average player before the age of 21 has already spent 10,000 hours playing video games and mastering new tasks. However, schools and educational institutions often struggle with

keeping their students interested in completing their courses (Roper 2006).

4. Profit or Non-Profit? Funding and Revenue

Ideally, the game would be developed as a non-profit project funded by a research body, institution, or third party sponsor. If that were impossible, then the game could be developed on the basis of its future revenue. This could be achieved by the sale of the game either online or in high street shops. A game or visualization that ran on a mobile device would be an excellent way to monetize a project with an app costing a small amount, such as $0.99. This small starting price can still generate large overall revenue due to the enormous size of the mobile market. The other option is to fund the project through advertisements, which would show up in the game. These, however, would have to be carefully chosen to comply with the ethical boundaries of the project. There are advertising networks in place for iOS and Android that allow easy integration of advertisements into an app. The third option would be to sell players virtual money with which they could pay for services and buy goods in the game. The choice of funding for the development and licensing of the game would depend upon the needs and resources of the client and the project.

5. Conclusions

Show me your children's games, and I will show you the next hundred years.

—Heather Chaplin and Aaron Ruby

It has long been understood that computer games can be useful tools in promoting teaching and learning. Playing a computer game can be rewarding, a benefit already recognized by educators two decades ago. Making games about archaeology using real ancient environments and modelled ancient personas will allow players to focus on details and landscapes, which can be looked at as long as they wish and explored at an individual pace. Exploration of a 'real' past world would also provide variety for gamers and such a game would create strong competition against the popular treasure hunting games, making players more aware of and attached to the 'light side of the force'.

The benefits do not stop there. Archaeologists, historians, sociologists, economists, and other social scientists could find archaeological computer games a refreshing, novel and marvelous research opportunity. By studying and observing the ways in which the players of the game interact with each other and their environments, researchers can gain a greater insight into the ancient patterns of behaviour, everyday life, and decision making. Such studies can then also be compared with data from agent-based modelling and network analyses, especially fruitful in MMORPG versions which tend to give players the feeling that they are members of an exclusive community.

A game such as proposed in this paper can become an experimental ground for the testing of new and different social and economic theories related to the past societies. It also provides fertile ground in which the field of experimental archaeology may develop – in short, a huge brainstorming machine. The virtual environment, however, should not be confused for the realities of the past; although it can, as a partial representation, give a feeling of participation in the past.

The next step in the process is the creation and implementation of one or several concrete case studies. This would allow developers, players, and researchers to test systems and approaches in a continuing and interactive way. If such studies were framed correctly, they would also provide the basis for meaningful scholarly research projects as well as provide valuable tools for those working in heritage and education as well as for the general public.

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References

Amazon.com. 2013. "Amazon Best Sellers: Best Sellers in PC Strategy Games." Accessed 23 September 2013. http://www.amazon.com/Best-Sellers-Video-Games-PC-Strategy/zgbs/videogames/229609.

Amory, A., K. Naicker, J. Vincent, and C. Adams. 1999. "The use of computer games as an educational tool: identification of appropriate game types and game elements." *British Journal of Educational Technology* 30 (4): 311–321.

Arnaud, R. 2011. "The Game Asset Pipeline." In *Game Engine Gems 1*, edited by E. Leyngel, 11–38. London: Jones and Bartlett Publishers International.

Bryce, J. and J. Rutter. 2001. "Presence in public computer gaming." Paper presented at Computer Games and Digital Textualities, IT University of Copenhagen, March 2001.

Calef, C., T. Vilbrandt, C. Vilbrandt, J. Goodwin, and J. Goodwin. 2002. "Making it Realtime: Exploring the Use of Optimized Realtime Environments for Historical Simulation and Education." Paper presented at Museums and the Web 2002, Boston, 18–20 April 2002.

Champion E. M. 2003a. "Applying game design theory to virtual heritage environments." In *GRAPHITE '03: Proceedings of the 1st International Conference on Computer Graphics and Interactive Techniques in Australasia and South East Asia*, edited by M. Adcock, I. Gwilt, and Y.T. Lee, 273–274. New York: Association for Computing Machinery.

Champion, E. M. 2003b. "Heritage Role Playing: History as an Interactive Digital Game." In *Expertise in Design: Design Thinking Research Symposium* 6, edited by Y. Pisan, N. Cross, and E.A. Edmonds. Sydney: Creativity and Cognition Studios Press.

Champion E. M. 2005. "Meaningful interaction in virtual learning environments." In *The Second Australasian Conference on Interactive Entertainment: University of Technology, Sydney, Australia, 23–25 November 2005*, edited by Y. Pisan, 41–44. Broadway: Creativity and Cognition Studios Press.

Champion, E. M. 2006. "Playing with a Career in Ruins: Game Design and Virtual Heritage." In *Learning in Cyberspace: New Media for Heritage Didactics and Interpretation*, edited by E. M. Champion. Barcelona: Museum of Catalonian History.

Champion, E. M. 2011. *Playing with the Past*. London: Springer-Verlag.

Chief Information Officer (CIO). 2007. "Remixing Çatalhöyük Launches." Accessed 25 June 2012. http://okapi.wordpress.com/2007/10/05/remixing-catalhoyuk-launches/.

Drew, Q. 2007. *Archaeology is a Brand!: The Meaning of Archaeology in Contemporary Popular Culture*. Oxford: Archaeopress.

Earl, G. P., S. J. Keay, and G. C. Beale. 2008. "Computer Graphic Modelling at Portus: Analysis, Reconstruction and Representation of the Claudian and Trajanic Harbours." In *Proceedings of EARSeL SIG Remote Sensing for Archaeology and Cultural Heritage*. Rome: Consiglio Nationale della Ricerca.

Earl, G. P., S. J. Keay, and G. C. Beale. 2009. "Evaluating Gismondi's Representation of Portus, the Port of Imperial Rome." In *Arqueologica 2.0, Proceedings of the 1st International Meeting on Graphic Archaeology and Informatics, Cultural Heritage and Innovation, Seville-La Rinconada, 17–20 June 2009*. Seville: Sociedad Española de Arqueología Virtual.

Earl, G. P., S. J. Keay, and G. C. Beale. 2010. "Archaeological Computing for Recording and Presentation of Roman

Portus." In *Proceedings of the First Portus Workshop, held at the British School at Rome, March, 2008,* edited by S. J. Keay and L. Paroli. Rome: British School at Rome.

Epic Games, Inc. 2012. "Foliage." *UnrealEngine3*. Accessed 25 June 2012. http://udn.epicgames.com/Three/Foliage.html.

Gallagher, M. D. 2011. "Essential Facts about the Computer and Video Game Industry: 2011 Sales, Demographic and Usage Data." Accessed 25 June 2012. http://www.theesa.com/facts/pdfs/ESA_EF_2011.pdf.

GRABstats.com. 2012. "Video Game Industry Stats." Accessed 25 June 2012. http://www.grabstats.com/searchresults.asp?searchterms=video+games.

Kalay, Y. E., T. Kvan, J. Affleck, and T. Kvan. 2007. *New Heritage: New Media and Cultural Heritage*. New York: Routledge.

Liestøl, G. 2009. "Situated Simulations: A Prototyped Augmented Reality Genre for Learning on the iPhone." *International Journal of Interactive Mobile Technologies* 3: 24–28.

Mosaker, L. 2000. "Visualizing Historical Knowledge Using VR Technology." *Digital Creativity SandZ* 12(1): 15–26.

Pujol, L. and E. Champion. 2012. "Evaluating Presence in Cultural Heritage Projects." *International Journal of Heritage Studies* 18(1): 83–102.

Raessens, J. and J. Goldstein. 2011. *Handbook of Computer Game Studies*. Cambridge: MIT Press.

Remondino, F. 2003. "From point cloud to surface: The modelling and visualisation problem." *International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV-5/W10*.

Rickman, O. and E. Wilson. 2010. "'A History of the World': British Museum Celebrates Success of Public Service Partnership and Looks to the Future." Accessed 25 June 2012. www.britishmuseum.org/about_us/news_and_press/press_releases/2010/annual_review_2009-10.aspx.

Roper, M. 2006. "Discover Babylon: Creating A Vivid User Experience By Exploiting Features Of Video Games and Uniting Museum and Library Collections." Paper presented at Museums and the Web 2006, Albuquerque, New Mexico, 22–25 March 2006.

Rüther, H. 2010. "3D Model Screenshots. Zamani Project." Accessed 25 June 2012. http://www.zamani-project.org/index.php?a=screenshotsandid=43.

Stoop, S. and A. Turner. 2007. "Games and Simulation: DS Online's Newest Topic Area." *IEEE Distributed Systems Online* 8(10): 1.

Tassi, P. 2011. "Steam Sales Estimated Close to $1 Billion in 2010." Accessed 23 September 2013. http://www.forbes.com/sites/insertcoin/2011/02/04/steam-sales-close-to-1-billion-in-2010/.

Tucker, G. and and J. Wallrodt. 2013. "Rethinking CAD Data Structures — Pompeii Archaeological Research Project: Porta Stabia." *The CSA Newsletter* 26(1). Accessed 23 September 2013. http://csanet.org/newsletter/spring13/nls1302.html.

Wallrodt, J. and G. Tucker. 2011. "1:1 Drawings Workflow." Accessed 25 June 2012. http://paperlessarchaeology.com/2011/07/10/11-drawings-workflow/.

Wallrodt, J., K. Dicus, L. Lieberman, and G. Tucker. 2013. "Beyond Tablet Computers as a Tool for Data Collection: Three Seasons of Processing and Curating Digital Data in a Paperless World." Paper presented at Computer Applications and Quantitative Methods in Archaeology Conference, Perth, WA, Australia, 25–28 March 2013.

Wang, L. and E. M. Champion. 2011. "A pilot study of four cultural touch-screen games." In *Proceedings of the 12th Annual Conference of the New Zealand Chapter of the ACM Special Interest Group on Computer-Human Interaction*: 57–64. New York: ACM.

Weyrich, T., M. Pauly, R. Keiser, S. Heinzle, S. Scandella, and M. Gross. 2004. "Post-processing of Scanned 3D Surface Data." Accessed 25 Oct 2012. http://www.cg.inf.ethz.ch/Downloads/Publications/Papers/2004/Wey04a/Wey04a.pdf.