PRESENTING ANCIENT HISTORY THROUGH SERIOUS GAMES: A CASE-STUDY IN ASSYRIOLOGY

by

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Abstract

This thesis investigates how ancient history can be effectively presented through serious games for educational purposes, by presenting a case study in the field of Assyriology. It is anticipated that the results are applicable to other fields of history and cultural heritage.

A model is presented to describe how heritage and historical content can be manifested in video games, for the design of serious games for heritage and the analysis of commercial games that present historical material.

The theories of reduced fidelity constrained virtual environments are applied to serious games for heritage, to reduce required development resources. A constrained implementation of a serious game for Assyriology is tested against an equivalent 3D environment, and results indicate the constrained environment can achieve comparable levels of presence, enjoyment, quality, and interest in the subject.

Based on an interview with an Assyriology field expert, a methodology for the analysis and design of serious games for heritage is presented, based on activity theory. The methodology is applied to the analysis and redesign of a serious game for Assyriology, and the development of a playable prototype. An online user-test showed the redesigned game was enjoyed by participants and was effective at achieving its learning objectives.

For Gitta.

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CAVE – CAVE Automatic Virtual Environments (plural CAVEs)
COTS – Commercial Off The Shelf
GFX – Graphics
HCI – Human-Computer Interaction
ICT – Information and Communication Technology
SGH – Serious Game for Heritage (plural SGsH)
HCG – Historical Commercial Game (plural HCGs)
NPC – Non-Player Character (plural NPCs)
UI – User Interface
VHE – Virtual Heritage Environment (plural VHEs)
VR – Virtual Reality

Chapter 1 Introduction

"If history were a photograph of the past it would be flat and uninspiring. Happily, it is a painting; and, like all works of art, it fails of the highest truth unless imagination and ideas are mixed with the paints."

– *Allan Nevins* (1954)

1.1. Interactive Technologies and Virtual Heritage

1.1.1. Interactive Technologies in History and Cultural Heritage

With the onset of the information age, there has doubtless been a great technological revolution throughout many sectors of industry, education, culture, and most aspects of everyday human activity. Businesses, institutions, and individuals now have access to powerful and cheaply available computing systems and digital hardware. This hardware is advanced enough to allow sophisticated real-time interactions between system and user, as well as global-scale networking utilising near-instantaneous communications. One area that has been, and continues to be, transformed by such interactive digital technology is the history and cultural heritage sector, which focuses on the preservation and transmission of the past, including tangible artefacts and remains, intangible human activities and customs, and natural landscapes. Such information can now easily be accessed, examined, and interacted with through a plethora of digital devices, by users both alone and collaboratively.

Many examples of interactive technologies for history and heritage have built upon and utilised their theory of motivation to learn from curiosity, interest, and flow. Examples include "wonder objects" (Rawat, 2005), which use digital technology to convert traditional museum artefacts into interactive experiences, and the presentation of heritage artefacts and learning resources through a museum visitor's own smartphone (Carillo *et al.*, 2010).

The field has by no means been restricted only to applications within museums; many forms of presentation of historical information have been identified (Foni, Papagiannakis and Magnenat-Thalmann, 2010) and included in various interactive applications, presented by a variety of stakeholders (Koutsabasis, 2017). One often-explored form of interactive applications is video games, which have been utilised in applications as wide-ranging as the exploration of collections of museum objects (Ridge, 2011) and for tourism (Xu, Buhalis and Weber, 2017), shown in Figure 1. However, due to their central role in this project, such video games for transmission of historical content will be described in more detail in later sections of this chapter.

Figure 1. Screen capture from the "Eye Shakespeare" gamified tourism app

The mobile application is an example of the gamification of cultural heritage. Reprinted from Xu et al. (2017), with permission from Elsevier.

1.1.2. Virtual Heritage

An important field within the application of interactive technology to history and cultural heritage is virtual heritage, which was first defined by Stone (1999) as "the use of computer-based interactive technologies to record, preserve, or recreate [artefacts], sites, and actors of historic, artistic, religious, and cultural significance and to deliver the results openly to a global audience in such a way as to provide formative educational experiences through electronic manipulations of time and space". Stone and Ojika (2000) also described the potential for applying technology and advances in virtual reality to the virtual heritage field.

Virtual heritage is typically closely linked to the concept of virtual environments, whereby an accurate and authentic representation of a cultural or historic site, as well as relevant actors, activities, and events, are presented through a (to differing degrees) navigable and interactive digital recreation (Devine, 2007). Such environments commonly make use of 3D textured polygonal technology, which Foni *et al.* (2010) concluded was the best compromise compared with other graphical means of presentation. However, other authors have criticised virtual heritage for not focusing enough on presentation of meanings in environments or on the needs and limitations of the end user (Tan and Rahaman, 2009).

One of the first examples of a virtual heritage application was an accurate 3D representation of the inside of Notre Dame cathedral (DeLeon and Berry, 2000), shown in Figure 2, but there has been a wide range of examples presented since, utilising different technology and techniques, and presenting different source material (e.g. Kim *et al.*, 2001; Gillam, Innes and Jacobson, 2010; Kenderdine, 2010; John *et al.*, 2017).

Figure 2. Virtual environment recreation of Notre Dame cathedral

Reprinted, with permission, from DeLeon and Berry (2000). © 2000 IEEE.

1.2. Games, Serious Games, and Game-Based Learning

1.2.1. Games and Play

The concepts of games and play are universally understood and accepted within many aspects of human (and even animal) behaviour, yet the exact definition of these terms is not agreed upon. Salen and Zimmerman (2004) offered one of the most generalised definitions of play as "the free space of movement within a more rigid structure", which described play in a game as the movement of the state of a game through a rigid possibility space, defined by the game's rules. Nevertheless, it is generally understood that play is an activity undertaken for the purposes of enjoyment and entertainment, and that games are organised structures of objects and rules designed to be played (with). The core rules and modes of interaction within games are known as game mechanics and have also had competing definitions offered (e.g. Sicart, 2008).

Games have been completely revolutionised by digital technology, and the resulting video games have achieved a state of wide proliferation, cultural significance, and commercial success. Video games are also played by both the young and old, with 66% of 18 to 24 year-olds in the UK playing video games "fairly often" or "very often", and a figure of 69% for people aged 60 and over (Statista, 2015). The commercial games industry has grown to even overshadow the film industry, with products ranging from "triple-A" games, produced with multi-million-pound budgets, to smaller "indie" games, produced by small teams with next to no budget.

1.2.2. Serious Games

The term "serious games" was coined by Abt (1975) and was popularised through a paper by Sawyer and Rejeski (2002), as well as the Serious Games Initiative (Rejeski and Sawyer, 2002). The term referred to (video) games created for purposes other than entertainment, especially for learning and education, training, skill transfer, or persuasion, although more definitions of the concept will be described in a following section. Since these publications, serious games have become a hugely successful academic and commercial sector (Laamarti, Eid and El Saddik, 2014; Moller and Hansen, 2016), and have been applied to fields as diverse as education (Shaffer and Gee, 2007; Cheng *et al.*, 2015), healthcare (Beale *et al.*, 2007; Rego, Moreira and Reis, 2018), sexual and social health (Ismail, Thammajinda and Thongpanya, 2019), and military training (Stone, 2012; Bhagat, Liou and Chang, 2016; Planchon *et al.*, 2018), such as that shown in Figure 3.

Figure 3. Screen capture from the military medical training serious game "3D-SC1"

3D-SC1 is a serious game to train soldiers in tactical combat casualty care. Reprinted from Planchon (2018), with permission from Elsevier.

It is generally accepted that all games have an inherent capacity for learning through the process of play, whether this be learning of properties and facts, attitudes, or systems, rules, and strategies. In typical entertainment games, the learned material is arbitrary and of no real-world significance. However, serious games are designed such that the material learned does have a useful real-world application. There have been several attempts to review the evidence of the effects of serious games, and they have generally reported positive results, although they are also often mixed or inconclusive (Connolly *et al.*, 2012; Boyle *et al.*, 2016; Zhonggen, 2019). One of the positive aspects of using a medium that many people are now familiar with, is that designers of serious games can utilise common game tropes and mechanics and be confident that players will recognise them and be comfortable interacting with them. However, this also has a drawback, because players will also approach serious games with certain expectations of the gameplay experience, in terms of quality and fun, and may be put off if these expectations are not met.

1.2.3. Game-Based Learning

One of the most successful applications of serious games has been in education and learning (De Freitas, 2006b), forming part of a wider field known as game-based learning, which is concerned with the use of games of all types in educational contexts. Empirical evidence in this field has found some positive results, but also some mixed results, and overall a lack of thorough and conclusive validation studies (Watson, Mong and Harris, 2011; Backlund and Hendrix, 2013; Girard, Ecalle and Magnan, 2013; Perrotta *et al.*, 2013; Hainey *et al.*, 2016).

One approach within game-based learning is that of utilising commercial video games, designed for entertainment purposes, within educational contexts. Such use typically requires careful analysis and selection of COTS games with learning potential (Rankin and Shute, 2010), as well as identification of parts of the game that are relevant to the lesson at hand (Breuer and Bente, 2010), and inclusion of the game within the structure of learning to be most effective. Nevertheless, due to the popularity and wide proliferation of video games, especially amongst today's school students, this approach has become more common (Bellotti, Berta and Gloria, 2010; Welsem, 2017; Casey, 2018), and has led to the advancement of associated experimental and evaluation techniques (McMahan *et al.*, 2011).

1.2.4. Definitions of Serious Games

Despite the extensive research devoted to serious games, there has been much discussion and contention over the term and how it should be defined. When Abt coined the term, he defined them as games that "have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement" (1975, p. 9). The essence of this definition has been retained in many offered since, such as "a serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment" (Michael and Chen, 2006, p. 17). However, these negative definitions of serious games have been found problematic by many researchers, who instead offer positive definitions, such as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (Zyda, 2005, p. 26), "digital games… to inform, influence, for well-being, and/or experience to convey meaning" (Marsh, 2011), "digital games with educational objectives" (Catalano, Luccini and Mortara, 2014), and "computer games that inform, train (instruct), or influence" (Champion, 2016). Finally, Ratan and Ritterfeld (2009) raise the issue that serious games can sometimes simply be "games that have been called serious by their publisher".

Despite the plethora of different definitions for what serious games are (or are not), there is one core concept that is common to all of them; that serious games combine the engagement and fun of games with the learning of instructional material. It is therefore considered useful to plot these two aspects as two orthogonal dimensions on a 2D map to show where serious games and other related concepts lie, as is shown in Figure 4.

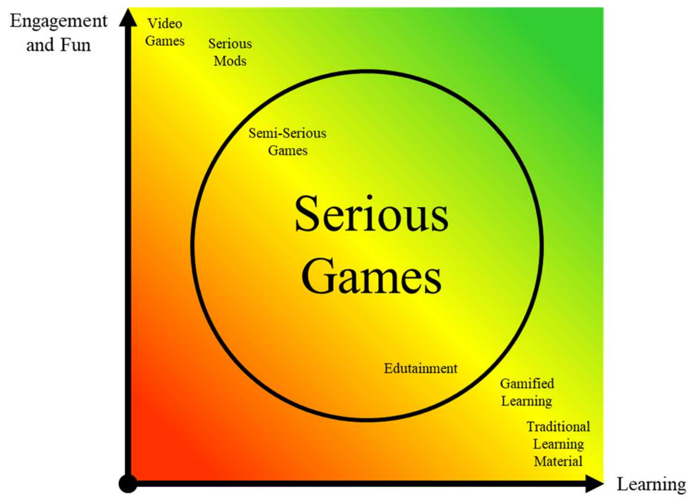


Figure 4. 2D map of serious games in terms of learning and engagement and fun

Serious games, video games, and traditional learning material are shown in their respective locations on the 2D map, along with some other related concepts.

Video games, in the top-left, are typically highly engaging and fun but lack real-world learning, whereas traditional learning material is effective for learning but considered unappealing. Serious games therefore sit in the 2D plane between these two extremes. Ideally, a serious game should successfully unite both aspects and sit in the green area at the top-right, but should avoid compromising either or both aspects, shown by the red area at the bottom-left. On this diagram are also shown several other concepts related to serious games. The first of these is "serious mods", which are modifications of commercial games, designed to build elements of learning (to the extent that is permitted by the base game and modification tools) onto a game already proven to be engaging (De Freitas, 2006a, chap. 2; Champion, 2013). "Gamified learning" represents the addition of game-like elements to traditional learning material in an attempt to increase its appeal and engagement (Deterding *et al.*, 2011; Landers, 2014). Next, a type of serious game frequently seen is one that includes learning material with engaging gameplay, but priority is given to the game, such that the player can choose to not learn any of the instructional material if they do not wish to. This type of serious game is here defined as a "semi-serious game". Finally, "edutainment" is an approach that was popular in the earlier years of serious game design and sits at the other end of the spectrum. These games gave priority to instruction rather than fun, often only utilising behaviourism to achieve learning objectives (Egenfeldt-Nielsen, 2007), and as such are often considered outdated and ineffective (Kirriemuir and McFarlane, 2004). It should be stressed that this 2D map is intended for the purposes of demonstration and is not proposing a model or conceptual framework of serious games.

1.2.5. Theories of Learning in Serious Games

Kenny and Gunter (2007) argued that when designing serious games, it cannot be assumed that learning inherent in the interactions of play will be sufficient to achieve the learning objectives; it must be based upon strong pedagogical foundations. Egenfeldt-Nielsen (2007) proposed that there are three "generations" of serious game, according to the pedagogical theories they employ. The first and worst generation uses only behaviourism, the middle generation uses constructivism, whereas the third generation uses constructionism and situated learning within the given socio-cultural context.

Pedagogical theories that have been used to support learning in serious games include the cognitive (Bloom, 1956), affective (Krathwohl, Bloom and Masia, 1964), and psychomotor (Simpson, 1966) domains of Bloom's taxonomy, Gagne's (1985) nine events of instruction, Keller's (1983) ARCS (attention, relevance, confidence, satisfaction) model, Kirkpatrick's (1994) four levels of training, Kolb's (1984) experiential learning model, as well as the theories of cognitive load (Chandler and Sweller, 1991), and flow (Csikszentmihalyi, 1991).

1.2.6. Technology of Serious Games

It is widely stated that the technological state-of-the-art of serious games is identical to that of commercial video games (Anderson *et al.*, 2010; Liarokapis *et al.*, 2017). Modern commercial games are developed using software known as game engines, which provide the technological foundations and functionality, including graphics, animations, audio, input, hardware communications, network communications, game logic functionality, and systems for saving and loading data from storage. Most serious games are now developed with the same engines used by the commercial game industry (Petridis *et al.*, 2012; Christopoulou and Xinogalos, 2017).

One aspect of modern video game technology that has recently received great interest is game analytics. These are network systems that, as the user is playing, silently connect to a server through the internet and send data relating to what the player is doing and how they are performing in the game. The publishers and developers collect this data and use it to analyse how the games are being played in the field, for making decisions related to feature design, bug-fixing, and monetisation. These analytics systems have drawn great interest in the field of serious games, where they represent a powerful and effective means to silently evaluate the effectiveness of instruction and learning in the serious game, without requiring cumbersome and invasive techniques such as questionnaires, interviews, or focus groups. One of the central aims of such analytics, known as game learning analytics, is therefore to find ways of effectively measuring the complex cognitive and affective processes of learning, only through the measurement of in-game interactions. As such, this field has now received high levels of academic interest and research (Hauge *et al.*, 2014; Shoukry, Göbel and Steinmetz, 2014; Loh, Sheng and Ifenthaler, 2015; Freire *et al.*, 2016; Serrano-Laguna *et al.*, 2017; Alonso-Fernández *et al.*, 2019).

1.2.7. Design of Serious Games for Learning

The challenge of designing serious games is to successfully combine both aspects of learning, through thorough pedagogical principles, and gameplay that manages to create a fun and entertaining experience, thereby moving into the upper-right section of the 2D map in Figure 4. Indeed, this is a very difficult challenge, not least because the commercial video game industry, after decades of evolution and investment, still struggles to understand and reliably create engaging games. Good games typically challenge the player while also giving them a joyous and rewarding interactive experience, in a way that is variously described as a "sweet spot", "hard fun", or "pleasantly frustrating" (Breuer and Bente, 2010). Serious games must achieve this while also introducing instruction and learning, since enjoyment in a serious game has been shown to influence the effectiveness of learning (Giannakos, 2013). Furthermore, learning in serious games has been shown to be most dependent on the design of the game in question, and is not simply enabled by the nature of the video game medium (O'Neil, Wainess and Baker, 2005).

It has been argued by many previous authors that this formidable challenge of successfully combining engaging gameplay with effective, deep learning, cannot be solved by combining components of play and learning together in an ad hoc manner, expecting the resulting serious game to be successful on both fronts. This has been expressed in some rather humorous ways, such as David Thomas's quote that one should not "try to peel the icing off the video game cake and lay it over the liver of learning and expect it to taste the same" (Michael and Chen, 2006, p. 30), or that a failure to find an effective blending of the two aspects will create something akin to "chocolate-dipped broccoli" (Bruckman, 1999). It has been argued that the activities of playing and learning must be as closely married and seamlessly integrated together as possible (Perrotta *et al.*, 2013; Ke, 2016; Ke *et al.*, 2019), by ensuring that instruction, learning, and feedback occur through the narrative and core mechanics of the serious game (Bellotti, Berta and Gloria, 2010; Grey *et al.*, 2017). Here, core game mechanics are defined as the principle interactions that form the majority of the gameplay experience, without which the game could not be played (Sicart, 2008). In a similar vein, an argument has also been levelled against gamification of learning, because it does not aim to achieve this deep level of integration, and simply attempts to loosely tie game and learning elements together (Ferrara, 2013).

Other approaches for the design of serious games include definition and completion of serious game design documents (Bergeron, 2006, chap. 8), promoting experiential learning and minimising cognitive load (Catalano, Luccini and Mortara, 2014), and carefully balancing the level of player agency compared with prescriptive scaffolded learning (Sawyer *et al.*, 2017). Research has also been conducted into designing serious games from the point of view of the target user's capabilities, limitations, and experiences of the end product (Ferrara, 2013), as well as evaluating participants' user experience of serious games (Moizer *et al.*, 2019).

1.2.8. Implementation and Evaluation of Serious Games for Learning

Once a serious game has been successfully designed and developed, it must be implemented with the target users in its context of use, potentially integrated with other forms of learning, and evaluated to ensure it is meeting its objectives of engagement and learning. Some authors have previously offered guidelines and advice for how best to implement serious games in classroom contexts (Beavis, 2012; Marklund, Backlund and Engstrom, 2014; Becker, 2017), some specialising in particular educational levels, such as primary schools (Kim *et al.*, 2017), secondary schools (Earp, Catalano and Mortara, 2015), or higher education (Vlachopoulos and Makri, 2017). There has also been considerable work looking into how best to evaluate serious games in these real-world contexts (Connolly, T. M., Stansfield, M. H., & Hainey, 2008; Hainey, Connolly and Boyle, 2010), including how to ensure the results and conclusions are quantifiable and scientifically sound (Lee *et al.*, 2014; Mayer *et al.*, 2014; All, Nuñez Castellar and Van Looy, 2016). Some have even proposed the use of physiological signals to measure learning, thereby avoiding the biases and inaccuracies inherent in subjective self-assessments (Wu, Tzeng and Huang, 2014). Despite these advances, it has nevertheless been stated that there is still a lack of rigorous scientific studies to evaluate the effects of applying serious games in real contexts (Boyle *et al.*, 2016), performed by researchers with no personal stake in the project (Backlund and Hendrix, 2013).

A further point of discussion is the fundamental relationship between serious games and other forms of learning, and how serious games should be designed and utilised accordingly, now and in the future. It is not unanimously agreed whether serious games should aim to one day be a total replacement for traditional forms of teaching and learning, whether they should be a tool to aid teaching and a vehicle for discussions, or whether they should be nothing more than a hook to catch players' interest, so that they will be more receptive to other forms of instruction (Breuer and Bente, 2010). Finally, it is also not agreed what the exact role of the instructor should be in a serious game; a facilitator, participant, subject matter expert, technical support advisor, or a combination of all of the above (Taylor and Sofia, 2015).

1.3. Serious Games for Heritage and Historical Commercial Games

1.3.1. Serious Games for Heritage

Serious games have naturally received great interest from the history and cultural heritage sectors as an effective way of presenting and educating with such information, and there have been many examples of such SGsH (Anderson *et al.*, 2010; Mortara *et al.*, 2014; Paliokas and Sylaiou, 2016), such as that shown in Figure 5. This interest is being directed towards serious games for several reasons. Firstly, due to their potential as a means of educating users in a way that is effective and naturally draws users' attention and engagement. Secondly, serious games have great potential for allowing users to interact with historical material, form connections with it, and find their own personal meanings in it, especially through the use of game narratives and storytelling (Malegiannaki and Daradoumis, 2017; Rizvic *et al.*, 2019). Next, serious games allow users to experience recreations of significant historical sites and environments, enabling deeper understanding of other cultures, past and present (Champion, 2017a). This ability of serious games to experience other places is aided by a high level of acceptance of the technology within the population, as past authors have reported that 78% of young students believe that virtual reality has the power to take the user to another time or place (Castaneda *et al.*, 2018). Finally, serious games for heritage can focus not only upon tangible physical artefacts (Kyriakaki *et al.*, 2014), but also intangible heritage, such as ceremonies, customs, beliefs, and cultural activities (Linaza, Moran and O'Connor, 2013; Aristidou *et al.*, 2017), which often do not receive as much attention (Doulamis *et al.*, 2017).

Figure 5. Screen capture from the serious game for heritage "Gates of Horus"

This serious game instructs players on New Kingdom Egyptian temples by presenting a navigable temple environment combined with instructional learning activities, interacted with through the core game mechanics. Reproduced with permission of BAR Publishing, www.barpublishing.com.

It is not surprising then, that many museums and cultural institutions have begun adopting serious games as a means of transmitting heritage and historical information (Kelly and Bowan, 2014; Bailey-Ross *et al.*, 2016). Many such institutions believe they must adapt to reflect the public they serve, and so must utilise media that their visitors are familiar with and want to interact with.

1.3.2. Learning in Serious Games for Heritage

The fundamental forms of learning that are afforded by serious games for heritage are, for the most part, similar to those covered for general serious games in Section 1.2.5.

It can be argued that serious games represent a promising medium for presenting and teaching history content, particularly ancient history. Firstly, this is because games provide "entertainment, learning and social interaction within a cultural context" which engage learning through gameplay and "focus on providing historical reconstruction and heritage awareness" (Koutsabasis, 2017). Champion (2008a) argues that serious games for heritage have a great capacity for experiential learning, whereby users can learn in a constructivist manner through interactions with the material, with a focus on "awareness, understanding, and sense of newfound ownership or appreciation of cultural diversity, authenticity, and significance". In this way, users create the knowledge gained, rather than merely receiving it passively (Mortara *et al.*, 2014). The problem spaces of simulation games have also been argued to be a promising means of presenting and teaching historical content (Mccall, 2012). Finally, through the use of hermeneutic environments, SGsH may also allow users to understand the meanings and cultural significance of those places, and so "interpret the cultural perspective of others", causing the transformation of a user's world view (Champion, 2014). Similarly, Ch'ng (2009) described how digital environments might allow users to take part in experiential archaeology, whereby they undergo similar experiences and feelings as our ancient ancestors. The experiential learning capacity of serious games may well make this an even greater possibility.

It can also be argued that SGsH are particularly suited to ancient history where, due to the length of time that has since passed, there are often very few remaining texts, physical artefacts, or structures, making it more difficult for some members of the public to gain an understanding and appreciation of the period and what it would have been like to experience it for themselves. Serious games represent a tangible article that users can experience and interact with. For some fields, the historical record may be contested, incomplete, or entirely missing, and such games should ideally represent this, and even give users opportunities to consider and reflect upon the limits of our knowledge about the past.

Finally, another relevant form of learning is meaning-making, which was introduced to the museums and cultural heritage domain by Lois Silverman (1993, 1995). The theory refutes the notion that museum learning is simply transmission of cultural knowledge from environment to visitor, but instead visitors are rational agents, who bring with them their own motivations, self-identity, and prior knowledge and experience. These factors influence the visitor's interactions with presentations of history and heritage, and through processes of imagination, reflection, and interpretation that take place both during and after the interaction, the visitor creates their own meanings of personal significance. Since its introduction, the theory has seen widespread use within the museum domain (Rounds, 1999; Cohen-Stratyner, 2013), and some use in serious games for heritage (Bailey-Ross *et al.*, 2016).

Further information on the background and theories of learning in history will be covered in Section 2.2.

1.3.3. Design of Serious Games for Heritage

As was stated in Section 1.2.7, it has been argued that, when designing serious games, the gameplay, instruction, and learning should be deeply connected and seamlessly integrated together. Within the history and heritage domain, one way that this integration of play and learning can be supported is to ensure that the actions of the player, when interacting with the SGH, are significant within the context of the material. In other words, the actions of the player in the serious game have real historical analogues, and those historical actions and activities that the player is simulating are important and have consequences within the historical field. It is anticipated that such an approach could help to enable experiential learning, as Champion (2008b) argued is one of the greatest advantages of serious games for heritage.

Furthermore, it is also proposed that the concept of meaning-making, covered in the previous section, could also be included into this design philosophy. Therefore, the serious game for heritage is designed in such a way that, as well as the activities of play and learning being tightly integrated, players are able to discover and create personal meanings for themselves from the material, through their interactions with the SGH. This concept will be referred to as "meaningful integration of play and learning" from this point onwards. This leads players to affective and empathetic responses which can lead to corresponding changes in cultural attitudes (Huang and Tettegah, 2014). This approach also aligns with that of Schaffer *et al.* (2005), who proposed that for learning in games to be effective, it must be personally meaningful to the player.

1.3.4. Challenges of Serious Games for Heritage

a) General challenges

There are many challenges associated with the design and development of serious games for heritage, not least how exactly SGH designers should achieve meaningful integration of play and learning, described in the previous section, while still achieving engaging and entertaining gameplay that offers a good balance of challenge which is neither boring nor overwhelming.

Erik Champion (2007, 2016, 2017a, 2017b), through his various writings, has outlined and described many of the different challenges faced by designers of both serious games for heritage and virtual heritage applications. These include the issues of violence, which is often present within historical source material, and how to present it in ways that are still acceptable for younger audiences, and how to present culturally sensitive material that still holds great cultural significance for people today, so must be treated respectfully, while still allowing player freedom in their interactions with it. Furthermore, he also explains that presentation of historical material typically requires telescoping between very different levels of focus, from micro to macro, to sufficiently describe the significance of artefacts, yet achieving this fluidly within a serious game without affecting player involvement is challenging. He also describes the challenges of the ubiquitous use of 3D models in virtual heritage, including their effective capture, preservation, storage, retrieval, and use in 3D environments. Finally, he also describes the fact that much heritage and historical material contains uncertainty, competing theories, or simply a lack of any knowledge at all, yet video games are a medium that are typically used for showing well-defined information in one given state.

Another related challenge is that of accuracy and authenticity of presentation in serious games for heritage, which is compounded by the fact that different groups (players, heritage experts, etc.) have been shown to have very different attitudes towards accuracy of historical content in video games (Copplestone, 2017). Furthermore, it has also been shown that many young students believe that creators of virtual heritage experiences have the ability to present the past as it truly was without any inaccuracy or bias (Castaneda *et al.*, 2018).

It has also been shown that the design and inherent characteristics of serious games for heritage can have a significant effect on players' learning and performance, because they can unintentionally favour or disfavour participants with particular cognitive characteristics when performing certain types of tasks (Raptis, Fidas and Avouris, 2019). It was found that during a visual search task in a serious game for heritage, participants' "Field Dependence-Independence" cognitive style had a significant effect on their eye gaze behaviour, which affected gameplay behaviour and so learning and task performance. It was concluded that designers of serious games for heritage must therefore consider differing participant cognitive styles when designing each type of serious game task.

Finally, other challenges of serious games for heritage include the graphical presentation and interaction with 3D historical environments that contain large amounts of text in the world geometry (Chiavarini *et al.*, 2019), as well as overcoming the conflict of narrative paradox, especially when using prescribed instruction (Bellotti, Berta and Gloria, 2010). This paradox states the incompatibility between games where the player is a free agent, able to interact how they wish, and the use of prescribed narratives or instruction, where the user has (next to) no agency. Serious games for heritage also require mixed development teams, encompassing different skills and areas of expertise, and finally, dissemination of serious games for heritage should also be maintained through a system of long-term support, preferably where content can be updated over time.

b) The Role of Audio-Visual Presentation

One area of significant challenge for designing and developing serious games for heritage is related to the presentation of historical material through visual and audio means, which is generally the dominant method. Through their use of modern graphical technology, the fields of digital heritage, virtual heritage, and serious games for heritage have advanced the capture, generation, and presentation of high-fidelity 3D textured polygonal models which aim to replicate, as far as possible, photorealistic visual representations of sites and artefacts (Kiourt *et al.*, 2017; Kontogianni *et al.*, 2017; Rahaman, Champion and Bekele, 2019; Tschirschwitz *et al.*, 2019), such as that shown in Figure 6.

Figure 6. Perspective render of a 3D model of the Rumeli Hisarı Ottoman fortress

The 3D models were captured and reconstructed through laser scanning, and the renders generated in Lumion. Reprinted from Tschirschwitz et al. (2019) under common licence[1].

However, despite 3D models being an effective means of presenting historical material (Foni, Papagiannakis and Magnenat-Thalmann, 2010), in SGsH it has been argued that visual presentation can take precedence over other important factors such as interactions, experience, and meanings (Tan and Rahaman, 2009). Michael and Chen (2006) laid out several fundamental pitfalls of serious games design to avoid, including the assumption that one should

[1] https://creativecommons.org/licenses/by/4.0/

always use the best available technology. Other authors have also asked whether 3D graphics and environments are even necessary in serious games to create a sense of immersion and provoke a response from the user (Westera *et al.*, 2008; Hainey *et al.*, 2016). Studies have shown experimental evidence that 3D virtual environments, viewed with head-mounted displays, are superior to 2D interfaces, viewed with traditional flat screens, for serious games in terms of reaction times, question task performance, attention, and inhibition control (Giglioli *et al.*, 2019). However, it is unclear whether this difference is due to the nature of the virtual environment itself or only the hardware used to interact with it.

c) The Role of Budget and Resources

The final area of challenge in serious games for heritage is that of budgets and resources required for development. It is widely recognised that game development, especially when using state-of-the-art technology and graphics, is very expensive, time-consuming, and resource-intensive. Serious games designers must grapple with these factors, while at the same time achieving their learning goals, and also managing player expectations in terms of the quality of audio, visuals, playability, and design. There have been past cases of serious games for heritage where the developers intended to create a gameplay experience comparable with commercial video games (Lucey-Roper, 2006), but development was cut short due to budget shortages (Crewdson, 2007). The former author suggested that a solution is to find greater sources of funding for SGH projects, and other authors have suggested that procedural content generation may help to reduce the resources required in development (Liarokapis *et al.*, 2017). However, it is still unclear whether such solutions are enough to fully address this issue, which arguably will become greater as the state-of-the-art in games and graphics technology advances further.

1.3.5. Commercial Historical Games

As was described by Anderson *et al.* (2010), as well as serious games for heritage, there are also many commercial video games, developed for entertainment purposes, that use historical and heritage content, whether they be artefacts, themes, characters, settings, or events. Such games are the subject of interest of the field of historical game studies (Chapman, Foka and Westin, 2017). There are various types of historical and cultural heritage information these video games portray, for example Koebel (2017) discussed the presentation of the concept of historical periodisation through several commercial historical strategy games. It is important to consider what exactly players might learn from playing such games. It can be stated that there is some degree of similarity between serious games for heritage and historical commercial games, in terms of their presentation of historical and heritage content, despite the fact that they are produced for very different purposes. Furthermore, while serious games are concerned with accurately portraying content without bias, commercial games will freely distort, obfuscate, or fabricate content if it serves the gameplay or narrative goals. Nevertheless, it remains somewhat unclear how deeply this similarity runs, or how it should be defined.

1.3.6. Implementation and Evaluation of Games in History Learning Contexts

As with general serious games, there has been extensive research devoted to implementing and evaluating serious games for heritage in real-world settings (Birchall *et al.*, 2012; Mortara *et al.*, 2013), including use in history classrooms integrated into traditional teaching methods (Watson, Mong and Harris, 2011). There is gradually more focus being applied to more complex and high-level concepts such as meaning-making, attitudinal change, affect, and understanding of culture (Economou and Tost, 2008), however the field is still faced with the same lack of rigorous and scientific evaluation techniques as general serious games (Hainey *et al.*, 2016).

Due to the number of commercial video games being produced containing historical or heritage content, there has consequently been a great deal of interest directed at whether such games could be repurposed for use in history education contexts, and evaluating their effectiveness at improving engagement and learning (McCall, 2016). Incidentally, a sizeable portion of this work has focused on utilising the "Civilization" series of games in classrooms (Squire and Barab, 2004; Squire, 2005; Pagnotti and Russell, 2012), which are historical strategy games covering many different periods of world history.

1.4. Assyriology and Mesopotamian History

Serious games for heritage have a great potential to allow users to explore regions and periods of history in a way that engages them first-hand and enables interaction, exploration, and experiential learning. Assyriology is one such field of ancient history, and it is used as a case study for SGsH in this project.

Assyriology is the study of the writings and history of Mesopotamia, a region in modern-day Iraq, Turkey, and Syria, which was a cradle of civilisation in the ancient world, where writing is thought to have first developed during the fourth millennium BC. This region is shown in Figure 7.

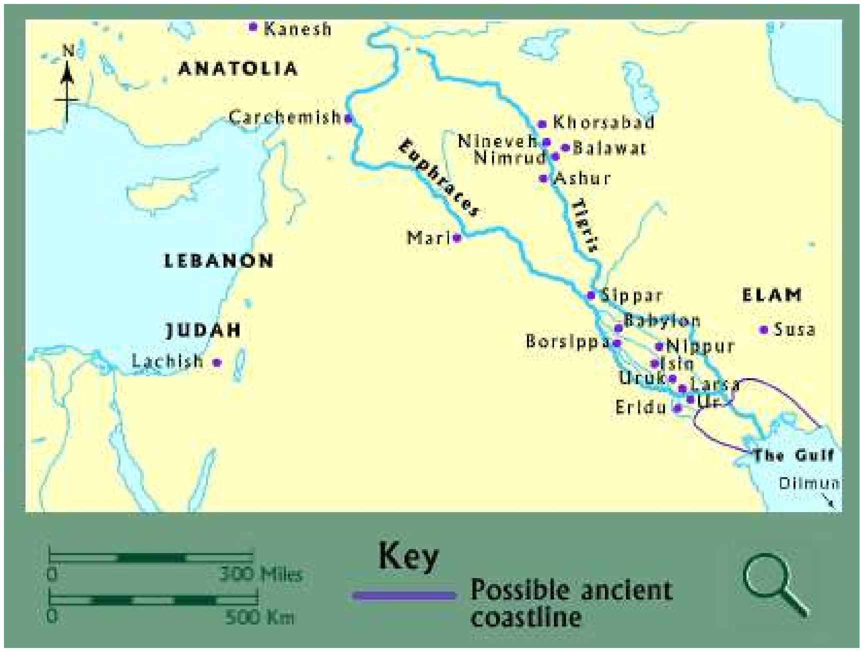


Figure 7. Map of ancient Mesopotamia and its major cities

© The British Museum.

The form of writing that developed in ancient Mesopotamia is known as cuneiform, which is formed from wedge-shaped imprints made in the surface of clay tablets, shown in Figure 8. Though it started as a bookkeeping tool to record wages, trade, and the flow of goods, writing soon permeated many parts of society throughout the region. Due to the durable nature of clay, large numbers of these tablets have survived to this day, and they have enabled historians to learn great quantities about their society, beliefs, rituals, and way of life (Finkel and Taylor, 2015). Assyriology has arisen as a field around the study of these artefacts, which depict many aspects of life throughout different civilisations in the region over a long period of time, from royal ceremonies to legal matters, everyday messages, and documents of trade.

Figure 8. A cuneiform tablet reconstructed from fragments

Photograph courtesy of The British Museum.

1.5. Thesis Overview

1.5.1. Project Aim and Primary Research Question

The primary aim of this project is to investigate how serious games for heritage can be designed and developed to present ancient history content, with the primary learning objectives of increasing user's levels of knowledge and interest in the relevant topic, by conducting a case-study specifically in the field of Assyriology and ancient Mesopotamian history. As was identified in Section 1.3.4, the level of resources required to develop such serious games for heritage is a primary concern, therefore part of this primary aim is to investigate design approaches that can be realised with more limited development budgets and resources. This aim can be expressed in the following primary research question:

How can serious games be exploited, using limited development resources, to increase users' knowledge of and interest in Assyriology and Mesopotamian history?

The reason for choosing to apply serious games for heritage to the field of Assyriology and Mesopotamian history is because there is a relative lack of attention the field has received from serious games and other interactive digital technologies. Furthermore, it is expected that many of the developments made investigating serious games applied to Assyriology will be generalisable to other periods of history and areas of cultural heritage.

1.5.2. Thesis Outline

Figure 9 shows a flowchart of the makeup of the entire thesis, and how each of the chapters form a thread-based logical flow from beginning to end.

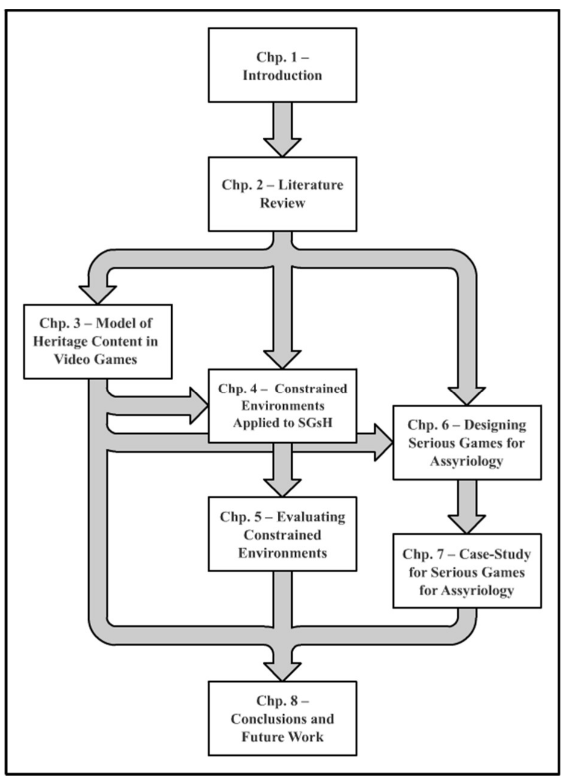


Figure 9. Flowchart of thesis chapters forming a logical flow

Chapter 2 will detail a literature review performed into the topics and bodies of literature that are most relevant to the project at hand. Based on this review, gaps in the literature will be identified and the primary research question will be broken down into a set of secondary research questions. These secondary research questions will naturally form three separate approaches, visible as the three parallel threads in Figure 9. The first of these approaches comprises only Chapter 3, in which a model of historical content in video games will be proposed and described. The resulting model will be used to inform and influence the research undertaken in each of the remaining approaches. The second approach comprises Chapter 4, in which a game engine and serious game for Assyriology will be presented, utilising theories of constrained virtual environments, and Chapter 5, in which the serious game will be evaluated experimentally against an equivalent serious game utilising traditional 3D environments. The third and final approach comprises Chapter 6, which will discuss the unique challenges of designing serious games for the field of Assyriology and will propose a new methodology to assist in the design and analysis of serious games for heritage, and Chapter 7, in which the value of the methodology will be shown through a case-study of the analysis, redesign, and subsequent user testing of a serious game for the Assyriology field. Finally, the findings of each of these three approaches will be drawn together into the thesis conclusions, covered in Chapter 8.

1.5.3. Thesis Themes

There are two themes which will run throughout the entire thesis, helping to connect the content together and form a cohesive whole. While these themes will not form a part of every research question, they will nevertheless be revisited throughout most of the chapters. The first of these will be the theme of historical content in video games, the different types of heritage and historical information that can be manifested through the video game medium, what forms these manifestations can take, what it means for players to be able to experience, interpret, and interact with this content, and how it can assist in achieving the learning objectives of the serious game. In its most fundamental terms, this theme relates to the notions of what serious games for heritage are.

The second theme of the thesis will relate to the concept of meaningful integration of play and learning activities in serious games for heritage, introduced in Section 1.3.3, whereby it is proposed that serious games for heritage should strive to seamlessly integrate gameplay with learning and instruction, in such a way that it enables players to find and create personal meanings for themselves. This theme will attempt to address what it means for serious games for heritage to meaningfully integrate learning and play, and especially how SGH designers might achieve this in reality. In its most fundamental terms, this theme relates to the notions of what makes a serious game for heritage effective.

1.6. Field Expert Interview

1.6.1. Interview Introduction

This section will detail an interview held with an expert in the field of Assyriology. This individual is Dr Jonathan Taylor, a curator and assistant keeper of cuneiform collections and Mesopotamia in the Middle East department of the British Museum[2]. He is an expert in many aspects of Mesopotamian history, especially cuneiform tablets and writings, but is also keenly

[2] https://www.britishmuseum.org/about_us/departments/staff/middle_east/jonathan_taylor.aspx

interested in how interactive digital technologies might be utilised to convey the subject matter in new and engaging ways.

This interview is being carried out to gain insights and information that will help guide aspects of the research over the remainder of the project, especially when considering how serious games should be designed specifically for the field of Assyriology, in Chapter 6. Serious games, especially those developed for history and heritage, are a highly multi-disciplinary field that requires input from multiple areas of expertise, including the historical field that is being focused on. The questions asked are shown in Table 1, and the responses are grouped into the physical assets and writings contained within the archaeological field of Assyriology, modern activities that occur in the field today, aspects of Assyriology that present unique challenges and opportunities for serious games for heritage, and finally what the interviewee believes are the most promising aspects of the field that could be presented through interactive technologies.

In your opinion, what are the greatest challenges of presenting Assyriology, cuneiform, and Mesopotamian history to the general public?
How does the British Museum approach these challenges?
In your opinion, what are the greatest opportunities of presenting Assyriology, cuneiform, and Mesopotamian history to the general public?
How does the British Museum capitalise on these opportunities?
Are there any aspects of Assyriology, cuneiform, and Mesopotamian history that you think would be particularly suited to the medium of educational games?
Do you believe there is potential in virtual recreations of Mesopotamian environments, which users can digitally walk through and interact with?

Table 1. Questions asked in the Assyriology field expert interview.

1.6.2. Assets in Assyriology

The expert explained that due to Mesopotamia's relatively wet climate, very little physical material has survived from the region compared with, for example, Egypt where the dry climate has preserved even some degradable materials. Therefore, we have very few degradable artefacts from ancient Mesopotamia, and as such we often know very little about them. Also, with some notable exceptions, there are very few buildings or physical structures that have survived. We have some information about the most important buildings, such as the temples, central areas, and perhaps some housing, but we do not know what Mesopotamian cities would have looked like, how tall they would have been, or what sort of vegetation or animal life would be living there, nor how people would have interacted with their environments.

However, because Mesopotamians wrote on clay, which does survive very well in such climates, there is an abundance of writing that has endured until the present, which allows us to "learn about them through their own words". Another aspect of Mesopotamian writings is the type of texts that we have access to, including everyday texts, not only writings they deemed important. We have access not only to the writings of the ancient historian who documented an event, but also "the schoolboy who did an exercise about it". Therefore, we know about their society, economy, everyday religion, as well as the state cult, medical matters, and other factors that affect people's daily lives. We also have private information such as letters and archives tracing many generations. These types of texts are generally much more relatable for the general public, because they were grappling with issues, often for the first time in human history, that are still relevant today, such as living in cities, literacy, and the concept of empire.

1.6.3. Modern Archaeological Activities in Assyriology

Next, the expert described the modern state of the field, whereby there is already a huge amount of writing that has been excavated, and this body of ancient literature is constantly expanding. However, the greatest challenge now, and the primary modern archaeological activity of Assyriology, is to reconstruct a clear, informative picture of knowledge from all of the fragments. One aspect of this is literally rebuilding pieces of broken cuneiform tablets back together to complete whole texts.

1.6.4. Challenges and Opportunities for Serious Games Unique to Assyriology

The expert described what he believed to be the greatest challenge in presenting Assyriology through serious games for heritage, that “nowadays very few people have actually heard of it”. Ancient Mesopotamian civilisations are not a part of the UK school curriculum, and as such, most people have a very low level of familiarity with the names, geography, cultures, and peoples. Mesopotamian history is a vast span of time and geography, and most of it might appear very alien to the public; unusual civilisations with “funny names”. For cuneiform specifically, people often don’t recognise it as writing. They also assume it is alphabetic and may struggle with the complexities of the scripts. However, older generations often had some familiarity with Mesopotamian history through the Bible, due to the cultures being mentioned in the Old Testament. Therefore, there were many ephemeral references to it within popular culture, however this level of familiarity does not exist anymore. Therefore, when presenting information “you have to go back to step one with absolutely everything”, so that you can “[bridge] the chasm of the lack of background knowledge”.

Nevertheless, despite this challenge, there are also clear opportunities. The public, when contacting this period of history for the first time, are very curious about the subject and they immediately want to learn more, especially experiential information. When they learn about cuneiform and Mesopotamian languages, they immediately ask “what did it sound like?”, and when they learn about buildings and artefacts they want to learn what they looked like and would have been like to experience first-hand. This is clearly a promising opportunity for presenting the subject matter through interactive technologies such as serious games for heritage.

1.6.5. Promising Directions for Presenting Assyriology through Serious Games

Finally, the expert illustrated what they believed is the most promising direction for presenting Assyriology through serious games, or any other interactive digital media; to try to understand how Mesopotamians would have seen their world with belief sets and understandings of an often cruel and dangerous world, that are completely different from our own. He expressed this as follows: “Part of the experience is not just different locations, it’s things like the heat, and the insects, and it’s going to be your physical health – that side of it. But it’s also the mindset, it’s completely different, so you need to somehow strip away the modern way of looking at things, of experiencing things, and put yourself in their shoes, what they know and what they could possibly know. What kind of feelings and emotions and responses those things would have triggered in them. You’re dealing with (from our point of view) incredible ignorance about the way the world works. You’re trapped in a world you don’t understand, you can’t understand. It’s incredibly frightening, you’re going to be ill, half of your children will die. Assuming they make it to birth, they’re going to die as babies, they’re going to get crippling diseases, half of them are going to have some crippling condition. You’re going to suffer some real problems, you’re going to be hungry a lot of the time. You’ll get, from our point of view, high levels of crime, violence, social problems. Your life and your expectations are going to be completely different”. Therefore, being able to present the perspective of these historical actors, allowing users to see the world through their eyes, is a promising direction for gaining a better understanding of that period.

1.7. Definitions of Terms and Concepts

There are several important terms and concepts that will be used throughout the rest of this thesis, where there is no single universally accepted definition, or where clarification is required. The following section gives a list of such terms and concepts.

Play – the definition given by Schell (2014, chap. 3) is used for the concept of play; “manipulation that satisfies curiosity”. This definition is broad enough to encompass the fact that playing may be done with no defined objectives or reasons, other than as an enjoyable activity performed for its own sake.

Game – the definition of a game given by Schell (2014, chap. 3) is used; “a problem-solving activity, approached with a playful attitude”. This definition is also broad enough to include many types of games, including those without specific goals or outcomes, but also defines the fact that most games include elements of problem-solving, and that they are used playfully, for the purpose of enjoyment and entertainment. Furthermore, the term “game” is also used as a shorthand for “video game”; a digital game played on electronic hardware. It will be made clear whenever reference is made to non-digital games.

Learning – a general working definition of learning is used; as the acquisition, internalisation, demonstration, and practice of new knowledge, skills, values, and competencies. Clear reference will be made when referring to specific theories of learning.

Commercial games – video games produced primarily for the purpose of entertainment. These games are usually produced commercially by businesses who expect them to make a profit.

Serious games – the definition of serious games given by Champion (2016) is used; "computer games that inform, train (instruct), or influence", which defines serious games by their positive functional attributes. However, although serious games are generally a form of digital video game, they can also be implemented through other forms of non-digital games, though this will be clearly indicated. The term "serious game" is generally used throughout this thesis to refer to serious games designed for education and learning.

Game-based learning – the literal definition of game-based learning is used, whereby games of all types (though predominantly digital video games) are used for learning purposes, often in educational contexts. These games could be serious games for learning or commercial games repurposed for educational use.

Gamification – gamification is used to refer generally to the concept of applying game elements in otherwise non-game contexts for the purposes of improving user engagement and experience. These game elements comprise a wide range of different systems, concepts, and mechanics.

History – history is used to refer to elements of the past, including events, actors, objects, places, periods, and processes, as well as their subsequent analysis, presentation, and use in education.

Cultural heritage – (cultural) heritage is used to refer to elements and characteristics created and passed down by past civilisations, that are still significant and valued by societies or individuals today. These include physical artefacts, buildings, landscapes, activities, customs, beliefs, traditions, and languages.

Serious game for heritage – serious games for heritage are serious games where the purpose is to educate and inform players about certain aspects of both historical and cultural heritage material. It is noted that within the academic field of serious games for heritage, *history* and *heritage* content are sometimes referred to interchangeably as *heritage*. However, within this thesis a distinction will be kept between the two terms throughout.

Historical commercial games – commercial (video) games which contain elements of historical or cultural heritage information in their narrative, theming, events, settings, mechanics, or characters. The use of the term "historical", rather than "heritage", is mostly coincidental. However, it is recognised that commercial games are typically more likely to present historical events and actors, whereas serious games are more likely to present heritage artefacts and customs.

Historical video games – an umbrella term, referring to all (video) games that contain historical or heritage content, whether they be serious games for heritage or historical commercial games.

Authenticity – Roussou's (2000) conception of authenticity in presentations of historical and heritage information is used; the "validity of information".

Accuracy – Roussou's (2000) conception of accuracy in presentations of historical and heritage information is used, referring to whether the method of presentation depicts that information as it is accepted, without changes or distortions. This concept is closely related to authenticity, and they are often used in conjunction.

Game immersion – the conception of immersion in video games, as described by Jennett *et al.* (2008), is used. This refers to the capacity of video games to engage players, drawing them in, potentially making them feel as though they were in the game world, and distracting them to the extent that they may lose awareness of the passage of time or events in the real world. This concept is commonly referred to simply as "immersion" but may be referred to as "game immersion" here to differentiate it from sensory immersion.

Sensory immersion – a concept used within the virtual reality field, referring to the extent to which a user's sensory perceptions of the real world are blocked out and replaced by perceptions of a virtual environment. The term is often used as a characteristic of hardware, such as head-mounted displays and insulating headphones. The concept is normally referred to only as "immersion" but is always referred to as "sensory immersion" within this thesis, to avoid confusion with game immersion.

1.8. Statements of Ethical Approval

This research project contains two experiments, conducted with human participants, detailed in Chapter 5 and Chapter 7. These experiments received full ethical approval from the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham under applications "ERN_15-1701" and "ERN_18-1913", respectively.

Chapter 2 Literature Review

2.1. Introduction

2.1.1. Chapter Introduction

This chapter will describe a literature review performed to underpin the work carried out in this project. To this end, it will begin with a brief description of the bodies of academic literature that are most relevant. The review will be formed from six different topics that will be addressed in turn. These will be a background on history learning, definitions and categorisations of historical video games, the design and evaluation of serious games for heritage, completed serious game for heritage projects, experiential concepts of video games most relevant to SGsH, and finally the theories and practice behind constrained virtual environments. Gaps in the reviewed literature will then be described. Finally, the chapter will be concluded by stating the research questions of the project, drawn from the identified research gaps, and describing how each one will be addressed by the remaining chapters of the thesis.

2.1.2. Relevant Bodies of Literature

The primary body of academic literature that will be drawn upon throughout this review and the entirety of this thesis is that of serious games. The serious games field is a large one that focuses on the analysis, design, development, implementation, testing, and evaluation of games for purposes other than entertainment, such as training, skill transfer, advertisement, behaviour change, and persuasion, though games for education and learning are the primary interest of this project. Some of the most notable publications in this field are Michael and Chen (2006), Susi *et al.* (2007), Breuer and Bente (2010), Bellotti *et al.* (2010), and De Gloria *et al.* (2014).

The top journals in the area are the International Journal of Serious Games[3], the International Journal of Game-Based Learning[4], and JMIR Serious Games[5], although other relevant journals include Computers & Education[6], the Journal of Computers in Education[7], the Journal of Computer Assisted Learning[8], and the IEEE Transactions on Games[9]. The most notable conferences include the International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)[10], the European Conference on Games Based Learning[11], and the Games and Learning Alliance (GALA) conference[12].

A sector of the serious games field that this project will draw upon specifically is that of serious games for heritage. Due to its smaller size and considerable overlap with the general field of serious games, the field of serious games for heritage does not have its own journals or conferences, but instead tends to be a considerable component of those relating to serious games in general. Some other journals that are related to the field include the ACM Journal on Computing and Cultural Heritage[13] and Digital Applications in Archaeology and Cultural Heritage[14]. Related conferences include the Museums and the Web conferences[15] and the Eurographics Workshop on Graphics and Cultural Heritage[16]. Notable publications in this field

[3] http://journal.seriousgamessociety.org/
[4] https://www.igi-global.com/journal/international-journal-game-based-learning/41019
[5] https://games.jmir.org/
[6] https://www.journals.elsevier.com/computers-and-education
[7] http://www.springer.com/education+%26+language/learning+%26+instruction/journal/40692
[8] https://onlinelibrary.wiley.com/journal/13652729
[9] https://cis.ieee.org/ieee-transactions-on-games.html
[10] http://www.vsgames.org/
[11] https://www.academic-conferences.org/conferences/ecgbl/
[12] https://conf.seriousgamessociety.org/
[13] http://jocch.acm.org/
[14] http://www.journals.elsevier.com/digital-applications-in-archaeology-and-cultural-heritage
[15] https://www.museweb.net/conferences/
[16] https://www.eg.org/wp/eg-events/graphics-and-cultural-heritage/

include Anderson *et al.* (2010), Mortara *et al.* (2014), Catalano *et al.* (2014), and Paliokas and Sylaiou (2016).

Finally, another separate but related field of academic literature is that of historical game studies, which is a sub-field within game studies that focuses on how video games represent and draw upon history and the past. Urichio (2005) is an influential publication, and Chapman *et al.* (2017) provided a thorough introductory paper for the field. Although this field covers some of the same topics and issues to serious games for heritage, the two fields are nevertheless quite separate, with little overlap.

This chapter, and the thesis as a whole, will draw mostly upon the field of serious games, and specifically serious games for heritage. However, where appropriate, references will also be made to the body of historical game studies.

2.2. History Learning

To provide a somewhat broader introduction to the application of serious games to history learning, this literature review will begin with a brief introduction to some of the most relevant background literature on learning history, both generally and specifically through museums.

2.2.1. General Background on History Learning

It can be stated that there are differing approaches and perspectives to both the nature of history itself, as well as the ways it can be presented and taught. Munslow (1997) proposed three different models of historiography, the methods of studying history; the *reconstructionist* approach, in which empirical evidence and reason are used to discover facts about the past; the *constructionist* approach, in which individuals use their own socio-cultural experiences and frame of thinking to judge the past; and the *deconstructionist* approach, which focuses on interpretations of representations of the past, rather than any discoverable objective reality. It has also been proposed that this categorisation could be further defined with a dimension of direct realism against impositionalism (Zeleňák, 2011).

Seixas (2000) defined three approaches to history education; the *best possible story* approach, in which a single most agreed-upon narrative of the past is taught through a "linear developmental process" (Squire and Barab, 2004), and is advocated by authors such as Downey & Levstik (1991). In the *disciplinary* approach, students must compare and weigh different perspectives of the past against one another. In the final *post-modern* approach, which Seixas (2000) argues for, the very ability of historians to describe the past without subjectivity and bias is questioned and reflected upon by analysing historical arguments. Furthermore, it was proposed that modern approaches to history education are driven by three "revolutions"; the transition from behaviourism to meaning-making, challenges to the nature of historical knowledge itself, and increased interest in collective memory and how we present the past (Stearns, Seixas and Wineburg, 2000). In a similar argument, Lévesque (2008) proposed that today's students should be taught historical thinking by focusing on five areas; *historical significance*, *continuity and change*, *progress and decline*, *evidence*, and *historical empathy*.

Finally, Carretero *et al.* (2012) argue that disagreements on how to teach history are, fundamentally, a "clash between the critical rationality of enlightenment and the individualism of romanticism". Yet teaching history effectively is now more important than ever, as changes in the modern world (the collapse of empires, globalization, digital presence) have created new identities seeking a historical basis to justify themselves.

Overall, it can be argued that serious games are a promising approach for teaching such constructionist and deconstructionist views of history, because players have a chance to actively experience and interact with historical content, and so through the act of play, are inherently engaging in an exercise of subjective historical interpretation. Indeed, it has also been argued that games can be an effective means of teaching students historical thinking (Squire and Barab, 2004).

2.2.2. Background on Museum Learning

Within the museum field, it has been argued that education and learning should be a primary aim of museums (Ames, 1988), and Csikszentmihalyi & Hermansen (1999) posited that museum learning is most effective when it is led by intrinsic motivation, and comes about through a process of *curiosity*, *interest*, *flow*, and finally *meaning and growth*. Finally, the concept of meaning-making, already described in Section 1.3.2, is also very relevant to learning in museum contexts (Silverman, 1993, 1995; Rounds, 1999).

Some models and methodologies for museum learning have also been proposed. Falk & Dierking (1992) presented the Interactive Experience Model to define the museum visitor experience, based on three factors; *personal context*, *social context*, and *physical context*. Kelly (2007) proposed the 5P model of museum learning, comprising *person*, *process*, *purpose*, *people*, and *place*. Finally, Marcus & Levine (2011) proposed a methodology for teaching students how to balance objective realities against subjective interpretations within a museum context.

Achieving effective museum learning through ICT, including serious games, has also become a subject of active academic research. Falk & Dierking (2008) extended their previous

Interactive Experience Model into 12 different factors, specifically targeting museum learning experiences using mobile technology. Kaptelinin (2011) proposed an approach for integrating ICT into museum displays, emphasising meaning-making and "how the learner changes". Finally, Wang & Nunes (2019) defined five primary museum learning objectives and described how each could be met using serious games.

2.3. Definitions and Categorisations of Historical Video Games

2.3.1. Serious Games for Heritage Literature

Within the body of serious games for heritage literature, several definitions, categorisations, and frameworks for SGsH have been proposed. Anderson *et al.* (2010) presented one of the first detailed reviews of serious games for heritage, providing many examples. They chose to categorise these into three groups; *prototypes and demonstrators*, which aim to reconstruct historical sites, along with the relevant historical events and actors, as accurately and authentically as possible; *virtual museums*, which aim to recreate and enhance a traditional museum experience with gaming technology, allowing users to view, manipulate, and analyse artefacts; and *commercial historical games*, which the authors consigned to a category of their own, arguing that such video games are typically not designed for educational purposes, but often contain some level of historical content, making them potentially suitable for use in education.

Mortara *et al.* (2014) presented a similar, comprehensive review of serious games for heritage. They chose, instead of categorising SGsH by their top-level characteristics, to categorise them by their intended learning outcomes. They therefore defined *cultural awareness games*, which focus on instruction of intangible cultural heritage (defined as "practices, representations, expressions, as well as the knowledge and skills, that communities, groups and, in some cases, individuals recognize as part of their cultural heritage" (UNESCO, 2003)) as well as awareness of other cultures and customs. They defined *historical reconstruction games*, which aim to accurately reconstruct historical sites, events, and actors as accurately as possible. Finally, they also defined *artistic/archaeological heritage games*, which instruct in tangible heritage and physical artefacts, and *architectural/natural heritage games*, which instruct in large-scale heritage such as structures, architecture, and natural heritage landscapes.

Antoniou *et al.* (2013) proposed a model of serious games for heritage, which defined several characteristics of the SGH, such as the instructional content and the skills the serious game develops; characteristics of the players, such as whether the serious game is played alone or in a group; and characteristics of the organisation that developed the SGH, such as the goals they wish to achieve with the serious game.

Finally, Schaller (2014) defined two possible approaches for the process of designing serious games for heritage. He defined *intrinsic design* as creating new and innovative game systems and mechanics that are based off of the instructional content itself, an approach that may achieve a strong integration of serious game mechanics and instructional content but entails more risk because there is no guarantee the resulting gameplay will be engaging and fun. He also defined *extrinsic design* as applying the instructional content as a "wrapper" to a well-proven set of game mechanics, an approach which entails less risk but is less effective at creating strong integration of serious game mechanics and instructional content.

2.3.2. Historical Game Studies Literature

Several definitions and models of general video games, though with particular focus on commercial games, that present history or heritage information have also been presented within the historical game studies literature. Uricchio (2005) proposed a spectrum of historical video games from *historically specific simulations*, which focus on the presentation of real historical sites, events, and actors, to *historically nonspecific simulations*, which instead present alternative historical scenarios or focus on historical models and processes from a more systems-based perspective.

Chapman (2016, chap. 3) also proposed a spectrum of historical simulations in video games. At one end of this spectrum is the *realist simulation style*, where a small number of historical events, actors, and sites are represented "as it was", often focusing on audio-visual presentation and borrowing many techniques and tropes from film. At the other end is the *conceptual simulation style*, which presents historical models and processes, usually as procedural systems embedded within the game mechanics themselves, and also often using abstracted and simplified visual representations.

Finally, McCall (2016) proposed a different spectrum. At one end are games where the player takes on the role of a single historical actor and must use that actor's abilities to overcome challenges they are faced with, such as role-playing and action games. At the other end are games where the player takes on the role of a more powerful agent with no true historical analogue, where they have access to knowledge and abilities that no single historical actor would have had, such as strategy games or "god games".

2.4. Design and Evaluation of Serious Games for Heritage

2.4.1. Frameworks and Methodologies for the Design and Evaluation of Serious Games

Within the serious games literature, many different frameworks, models, and methodologies have been proposed for the design, analysis, and evaluation of general serious games. This section will give a brief overview of the past and current state of this body of literature, and how it relates to the design and evaluation of serious games for heritage.

a) Initial Conceptual Frameworks

Earlier work in the serious games field saw the emergence of several high-level conceptual frameworks based on thorough pedagogical foundations, which arguably shaped current work in the field.

Gunter *et al.* (2006) proposed the RETAIN framework, which argued for the close integration of play and learning activities, based on sound pedagogical principles, and applied it to the analysis of serious games (Gunter, Kenny and Vick, 2008). The framework is formed from a set of insight-gaining questions, based on Bloom's Taxonomy (Bloom, 1956; Krathwohl, Bloom and Masia, 1964; Simpson, 1966), Keller's (1983) ARCS model, and Gagne's (1985) 9 Events of Instruction, which all continue to be influential pedagogical theories for serious games to this day.

De Freitas and Oliver (2006) presented the four-dimensional framework that models learning through video games in the following dimensions; *the context of learning*, *the attributes of the learners*, *the internal representations used by the game*, and *the pedagogic foundations and* *processes of learning*. The Game Object Model II (GOM II) framework was presented by Amory (2007), as a follow-up to the original GOM framework (Amory *et al.*, 1999), which used an object-oriented paradigm to model serious games in six dimensions; *game definition*, *authentic learning*, *narrative*, *gender*, *social collaboration*, and *challenges-puzzles-quests*.

Finally, more recently Yusoff *et al.* (2009) presented a high-level conceptual framework of serious games to describe their composition and the interactions and relationships between their principle elements. The authors also validated the framework using the Technology Acceptance Model (Yusoff, Crowder and Gilbert, 2010).

b) Literature Review of Recent Frameworks and Methodologies

Table 2 gives a more comprehensive review of serious games frameworks and methodologies presented within the last five years. This review is not intended to be an exhaustive collection, and instead aims to show the most important publications that define current trends and directions in the serious games field. Criteria applied to these publications were that they were all published since 2014 and presented a methodology or framework applied to serious game design, development, analysis, or evaluation.

Publication	Framework Name	Framework Type	Focus	Description	Components	Evaluation/Validation
(Argasiński and Węgrzyn, 2019)	–	Low-level conceptual framework	Affective serious games	Extends the concept of game design patterns, by including components of learning and affective response.	ECD model, DPE model, game design patterns	Design of a serious game for occupational health and safety training
(Wang and Nunes, 2019)	–	High-level conceptual framework	Serious games for heritage	Defines museum educational roles and serious game types and proposes a cross-reference for which best correspond to each other.	Museum educational roles, serious game types	None
(Rosyid, Palmerlee and Chen, 2018)	–	Low-level conceptual framework	Procedural content generation	A procedural content generation and mapping system for creating educational content for a given set of game mechanics.	Knowledge space, game content space, mapping between spaces	Case-study of the development of a serious game with experimental evaluation
(Serrano-Laguna *et al.*, 2018)	–	Methodology	Game learning analytics	A methodology using game learning analytics for validation and evaluation. The SG is designed to elicit performance that is measured through analytics to confirm successful learning.	Design and implementation stage, validation stage, deployment stage	Case-study of the development of a serious game with experimental evaluation
(Andreoli *et al.*, 2017)	FRACH	Methodology	Serious games for heritage	Extends the ISO quality-in-use model and presents a design methodology as an iterative loop with four phases.	Preliminary phase, conceptual phase, development phase, evaluation phase	Case-study of the development of a serious game for heritage with experimental evaluation
(Lameras *et al.*, 2017)	–	Low-level conceptual framework	–	Based on a literature review, they present the principle characteristics of serious games, as well as typical values which are best combined together.	Learning attributes, game attributes, outcomes, feedback/assessment, teacher roles	None
(Lope *et al.*, 2017)	Graphical Notation Methodology	Methodology	Serious game narrative	A methodology that focuses on the development and use of narrative at the core of the serious game. Made up of six phases.	Design of chapters, design of scenes, design of educational challenges and assessment, design of emotional experience, design of adaptation, design of collaboration	Case-study of the development of a serious game for heritage
(Roungas, 2016)	Model-Driven Framework	Low-level conceptual framework	Game design document	A framework based on their conceptual model of serious games, which focuses on the creation of a thorough game design document.	Challenges, goals, levels, game mechanics, feedback, relationships between game elements	Created a web-tool based on the framework, with evaluation with SG experts
(Carvalho, Bellotti, Berta, *et al.*, 2015)	ATMSG	Low-level conceptual framework	–	A model of serious games based on activity theory, using three central activities, each of which is made up of actions, tools, and goals.	Gaming activity, learning activity, (intrinsic/extrinsic) instructional activity, actions, tools, goals	Evaluated against LM-GM with serious games students, extended into a Service-Oriented Architecture (Carvalho, Bellotti, Hu, *et al.*, 2015), and extended with game learning analytics (Callaghan *et al.*, 2018)

(Arnab *et al.*, 2015)	LM-GM	Low-level conceptual framework	–	A framework which defines serious games as being made up of serious game mechanics, which are made from the combination of learning mechanics and game mechanics.	Serious game mechanics, learning mechanics, game mechanics	Evaluated against GOM with students and experts
(Lepe-Salazar, 2015)	GAGE	Explorative questions	–	Uses a thorough pedagogical basis to pose insight-gaining questions of a serious game, across several categories.	Stakeholders, goal, audience, game environment, enhancing the experience	Case-study of the analysis of a serious game
(Degens, Bril and Braad, 2015)	Three-Dimensional Model	Low-level conceptual framework	–	A framework consisting of three dimensions, that focuses on the interactions between each dimension.	User properties, game mechanics, learning objectives, game-user, game-learning, user-learning	Case-study of the analysis of two serious games
(Aslan and Balci, 2015)	GAMED	Methodology	–	A methodology, based on methods, rules, and postulates, embedded within a software design lifecycle.	Game design phase, game software design phase, game implementation and publishing phase, game-based learning and feedback phase	None
(Ghannem, 2014)	–	Low-level conceptual framework	Evaluation for educational use	A framework for educators to evaluate and select serious games.	Scenarisation, game theory, pedagogy	Case-study of the analysis of three serious games
(Tang and Hanneghan, 2014)	Educational Game Design Methodology	Methodology	–	A taxonomy of pedagogical elements combined with a waterfall-style methodology for serious games.	Tasks and problems in scenario, relationship of in-game components, properties of in-game components, plan, prototype, finalise	None
(Lim *et al.*, 2014)	NSGM	Low-level conceptual framework	Serious game narrative	Extends the concept of serious game mechanics to include a narrative element. They propose three types of narrative serious game mechanics and how to implement each.	Exposition, guidance, reflection and feedback	None
(Hall, Wyeth and Johnson, 2014)	–	Low-level conceptual framework	Embedding instruction in core game mechanics	Based on a loop of elements, each with implementation questions, to ensure the instruction is embedded in the serious game's core mechanics.	Goal, choice, actions, rules, feedback	Case-study of the development of a serious game with experimental evaluation (Hall, Wyeth and Johnson, 2016)
(Landers, 2014)	Theory of Gamified Learning	High-level conceptual framework	Combining serious games and gamification	A conceptual framework of game elements, user behaviour, and learning, and the causal relationships between them.	Game characteristics, instructional content, behaviour/attitude, learning outcomes	Case-study of the development of a serious game with experimental evaluation (Landers and Landers, 2014)
(Saavedra *et al.*, 2014)	–	Methodology	–	A system of matching technical competencies to serious games, built into a traditional software development methodology.	Pedagogic elements, technical aspects, integration aspects, requirements, design, development, testing, post-mortem	Case-study of the development of a serious game with experimental evaluation
(Barbosa *et al.*, 2014)	–	Low-level conceptual framework	–	The main game is divided into levels, and learning mechanisms are undertaken in parallel, where the instruction and learning takes place.	Levels, missions, learning mechanisms	Case-study of the development of a serious game

Table 2. Literature review of recent frameworks and methodologies for design and analysis of serious games

Out of these reviewed frameworks, two are considered deserving of particular focus. ATMSG (Activity Theory-based Model of Serious Games, Carvalho, Bellotti, Berta, *et al.*, 2015) provides a thorough model of the processes of play, learning, and instruction, how they are applied to a serious game from high-level to low-level implementation, and how they interact with one another, through the paradigm of activity theory. The model introduced by Hall *et al.* (2014) provides a means to ensure the instructional content of a serious game is embedded effectively within the core game mechanics. Therefore, when a user interacts with these mechanics, they will inherently go through a process of instruction and learning, and so achieve the serious game's learning objectives. For these reasons, these two frameworks are considered to be the current state-of-the-art in serious game design and analysis.

c) Frameworks and Methodologies for Serious Games for Heritage

There are a very limited number of conceptual frameworks and methodologies proposed within the literature, specifically for the design, development, analysis, or evaluation of serious games for heritage. The methodology presented by Wang and Nunes (2019) suggests which serious game genres should be used to achieve different museum educational roles, but no further advice is given for the low-level design of these serious games. The methodology presented by Andreoli *et al.* (2017) is made up of a preliminary phase, followed by conceptual, development, and evaluation phases organised into an iterative loop. The authors include details and descriptions of the activities and steps to undertake in each of these phases. However, the methodology does not address many specific requirements or characteristics of serious games for heritage.

Another methodology for developing serious games for heritage was presented by Zin *et al.* (2009), based on the results of an investigation into what school students want and need from serious games for teaching the history curriculum in Malaysia. The methodology is divided into two principle components; pedagogy and the digital game, which combine to achieve student engagement and cooperation. They also present a five-stage methodology for developing SGsH, made up of *analysis*, *design*, *development*, *QA*, and *implementation and evaluation*. Finally, Zin and Yue (2009) also presented a methodology for embedding historical learning in a serious game, based on five stages; *attract attention from player*, *game objectives*, *learning activity*, *learning content*, and *student assessment*.

2.4.2. Design and Evaluation of Virtual Environments for Historical Learning

a) Approaches for Virtual Heritage Environments

Roussou (2008) presented a thorough overview of virtual environments for historical learning, describing the subject from three different perspectives; *representation*, which concerns topics such as accuracy, authenticity, photorealism of visualisations, and interpretations; *experience design*, including interest, empathy, imagination, characters and the presence of life, and the use of multi-sensory hardware such as CAVEs; and *interaction*, including the dichotomy between expert mediation and self-guided agency.

More recently, Mortara and Catalano (2018) presented a treatment of virtual heritage environments, discussing the potential strengths of such environments for historical learning, focusing on their ability to recreate an holistic experience of an historical site, including all of the sights, sensations, and historical actors. They argue that the most important aspects of VHEs are immersion, accuracy and rigour, the completeness of the experience in an interactive world, and multi-sensory hardware.

Some authors have argued that many VHEs tend to focus too heavily on audio-visual presentation of historical environments. Champion (2008b) claimed that such environments should instead focus on contextual understanding and experience, recreated by first gaining a deeper understanding of our phenomenological and hermeneutic understanding of places, and then reproducing them within virtual environments. Similarly, Tan and Rahaman (2009) argued that VHEs should focus on meaning interpretation instead of visual presentation by combining the advantages of serious games for heritage with constructivist virtual environments and hermeneutic environments. Falconer and Scott (2018) attempted to implement these theories by evaluating a virtual reconstruction of Avebury Henge using phenomenological, and to a lesser extent phenomenographical, techniques. They concluded that the VHE could achieve a genuine experience of the site, although it was significantly different from the real-world experience of the modern-day site.

b) Frameworks for Virtual Heritage Environments

A limited number of conceptual frameworks have also been proposed for analysing, designing, and evaluating virtual environments for historical learning. Bonini (2008) presented a framework for VHEs based on supporting embodied and embedded cognition in the virtual environment, based on several factors; *experiencing*, *meaning-making*, *embodied and situated action*, *co-creation of meaning in the community of practice*, and *forming and re-forming of narratives*.

Rahaman (2018) presented a somewhat more general framework for digital heritage interpretation, the process of learning, communicating, and managing heritage, though it is highly relevant to virtual heritage environments. The framework was divided into four approaches; *effective presentation*, *cultural learning*, *embodiment and embodied interaction*, and *dialogic interaction*.

Bakar *et al.* (2013) produced a set of guidelines for designing VHEs through a series of expert interviews, categorised into *content-related items*, *experience-related items*, *setting-related items*, *support-related items*, and *interface-related items*. Similarly, Ibrahim and Ali (2018) proposed a framework for the design of virtual environments for historical learning, developed through several stages of consultation, design, and review. It was divided into four categories; *environment setting* and *navigation mechanism* (which together form a virtual walkthrough), and *information presentation* and *information design* (which afford cultural learning). Due to the recency, the specificity of the framework to VHEs, and the thorough nature of the development process, this framework is considered as the current state-of-the-art for designing virtual environments for historical learning.

2.5. Serious Game for Heritage Projects

Other researchers, such as Anderson *et al.* (2010), Mortara *et al.* (2014), Paliokas and Sylaiou (2016), and Malegianniki and Daradoumis (2017) have already given thorough reviews of serious games for heritage released up to their respective dates of publication, therefore the purpose of this section of the literature review is to give an overview of serious game for heritage projects completed since these publications. Table 3 shows a review of SGsH released within the last three years, which is not intended to be an exhaustive collection, but instead represent the most influential projects and demonstrate current research trends in the serious games for heritage field. Criteria for inclusion in this review were that the project be a serious game for heritage, rather than simply a virtual museum, virtual reality experience, or interactive application with no serious game elements. The projects also had to have been presented in an academic publication, first published in 2016 or later. Screen captures from some of these SGsH are shown in Figure 10.

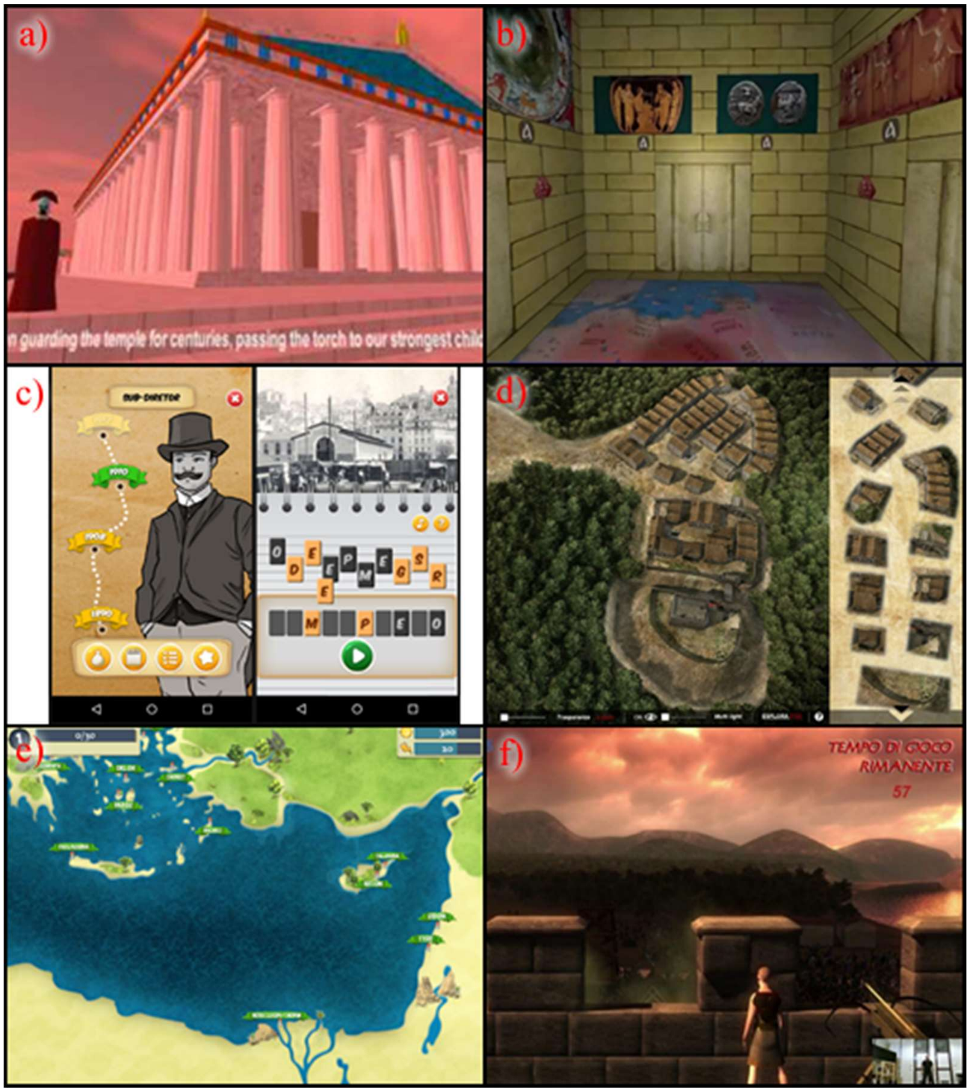


Figure 10. Screen captures from recent serious game for heritage projects

a) "Trials of the Acropolis", reprinted from Chintiadis et al. (2018) by permission of Springer, © 2018 Springer; b) "The Thracians", reprinted from Márkus et al. (2018); c) "1910", reprinted from Cruz et al. (2017) by permission of Springer, © 2017 Springer; d) "Yrsum", reprinted from Gabellone et al. (2017). © 2017 Elsevier Masson; e) "The Seafarers", reprinted, with permission, from Philbin-Briscoe et al. (2017). © 2017 IEEE; f) "Protect The Walls!", reprinted from Forlani et al. (2016) under common licence[17].

[17] https://creativecommons.org/licenses/by-nc-nd/4.0/

Name	Publication	Game Genre	Field/Historical Period	Target	Design Methodology	Evaluation
Minoans	(Barandoni, Jasink and Valinoti, 2019)	Boardgame	Minoan Crete	School students	Gamification of museum environment based on existing boardgames	None
Find the Artwork Behind the Story!	(Vayanou *et al.*, 2019)	Storytelling boardgame	Art history	Art museum visitors, general public	Based on an existing storytelling boardgame and developed through user studies	Play-testing sessions and focus groups
Oteiza Para Todas	(Bossavit *et al.*, 2018)	Mini-games	Jorge Oteiza, art history	School students	Three design sessions held in collaboration with a museum	Evaluation with primary and secondary school students
Trials of the Acropolis	(Chintiadis, Kazanidis and Tsinakos, 2018)	Adventure, mini-games	Ancient Greece	3rd grade Greek history students	A process of story design, asset design, and implementation	None
Myth Troubles	(Evangelopoulou and Xinogalos, 2018)	Adventure, quiz	Greek mythology	Primary school students	Educational Games Design Model (Ibrahim and Jaafar, 2009)	Evaluation with school teachers
The Thracians	(Márkus *et al.*, 2018)	Virtual tour, mini-games	Ancient Thrace	School students	Not specified	Evaluation with school students
Mission Opalchenets	(Noev *et al.*, 2018)	Puzzle, quiz	19th Century Bulgarian military history	School and university students	Bloom's Taxonomy (Bloom, 1956), and a process of game content design, knowledge design, and multimedia resource design	None
Archaeogame	(Noguera *et al.*, 2018)	Puzzle	Neolithic archaeology	Museum visitors	Not specified	None
Memorial Quest	(Volkmar, Wenig and Malaka, 2018)	Location-based, mini-games	Various cultural heritage in cities	General public	Sandbox SGH design presented by Bellotti *et al.* (2012)	Evaluation with university students
VR Terracotta Army	(Zhang *et al.*, 2018)	Virtual tour, mini-games, puzzle, quiz	The Terracotta Army	Museum visitors	Process of cultural heritage resources, digital scheme design, and key technology integration	None
–	(Drosos *et al.*, 2017)	Virtual tour, puzzle, quiz	El Greco, art history	School students	Constructivist learning theories, and requirements specification	Pilot evaluation with primary school students
Black Death	(Salomao *et al.*, 2017)	Role-playing game	The Black Death	School students	Requirements specification, and class-based functional design	Usability test with school students
Hippocratica Civitas Game	(Andreoli *et al.*, 2017)	Virtual tour, puzzle	Palazzo Fruscione, Italy	Archaeological site visitors	FRACH	Evaluation with university students
–	(Cesaria *et al.*, 2017)	Puzzle, mini-games	Sammichele di Bari, Italy	School students	Process of gamification of learning	None
1910	(Cruz, Carvalho and Araújo, 2017)	Mobile game, adventure, role-playing game	Portuguese revolution	School students	Learning principles of Gee (2003), and several stated principles of serious game learning	None
Heritage Hunt	(de Kock and Gómez Maureira, 2017)	Mobile game, role-playing game	Museum collections	Museum visitors	Several defined stages of serious game development	Evaluation with museum visitors
Yrsum	(Gabellone *et al.*, 2017)	Puzzle	Medieval Italy	General public	Use of scientific data in an edutainment game	None
–	(Kouřil, 2017)	Simulation	Underwater archaeology	Not specified	Specification of learning outcomes and possible interaction mechanisms	None
Urano: Invasion of the Thieves of Planets	(Lope *et al.*, 2017)	Point-and-click, adventure	Various periods of ancient history	School students	Graphical Notation Methodology	None
The Seafarers	(Philbin-Briscoe *et al.*, 2017)	Trading	Classical Mediterranean maritime trade	General public	Creation of game mechanics and content based on historical data	Evaluation with experts, and evaluation with the general public (Poullis *et al.*, 2019)
The Teos of Dionysos	(Varinlioglu *et al.*, 2017)	Puzzle	Ancient Greece	General public	Process of facts, narrative, game design, prototype, release	Evaluation with university students
HLMG	(Yue and Ying, 2017)	Mobile game, adventure, puzzle, quiz	Malaysian history curriculum	School students	Design to deliver history syllabus content through interactive game-based learning	Focus groups of school students
Protect the Walls!	(Forlani *et al.*, 2016)	Gesture controls, strategy	Ancient siege warfare	Primary and secondary school students	Historical and scientific information provided through hints, used by players to succeed at the arcade gameplay	None

Singapore Surrenders!	(Gaydos *et al.*, 2016)	Card game, timeline game	Singapore in WWII	Secondary school students	Process of educational goals, requirements specification, and game mechanics selection	Evaluation with school students
Gocha	(Georgiadi *et al.*, 2016)	Pervasive game, role-playing game	Archaeology	School students	Process of educational goals, system requirements specification, and game design with MDA (Hunicke, LeBlanc and Zubek, 2004)	None
–	(Giannakopoulou, Kokkalas and Kaliampakos, 2016)	Open-air game, team-based, role-playing game, puzzle	Souli region, Greece	General public	Process of scenario, aesthetics, technology application, story, characters, surrounding space, paper material, and digital devices	None
GeoQuest Vesuvius	(Maraffi, Sacerdoti and Scamardella, 2016)	Role-playing game	Eruption of Vesuvius	School students	Use of a role-playing design, based on motivation, cooperation, identification, narration, exploration, review, and planning	Evaluation with secondary school students
Jesuit Missions	(Rigo *et al.*, 2016)	Mobile game, mini-games, virtual reality	Jesuit missionaries in Brazil	School students	Process of technology as a suitable and relevant tool, and a playful space of a game as the background	Workshops with primary school teachers

Table 3. Literature review of recent serious game for heritage projects

Furthermore, a small number of serious games for heritage specifically for presenting Assyriology and Mesopotamian history have been observed, although not within the above review. Lucey-Roper (2006) presented Discover Babylon, a 3D puzzle adventure game about Mesopotamian society for school students, shown in Figure 11. The serious game was designed through collaboration between the different stakeholders in a process of serious game goals, identification of artefacts to include, and development of the environments, and it was evaluated with museum visitors and members of the public. The British Museum produced a set of ten small SGsH for their Mesopotamia website (The British Museum, 2006b), covering different periods and aspects of Mesopotamian history for school students.

Other interactive digital projects for Assyriology include Babylon 3D[18], a virtual heritage recreation of the ancient city of Babylon; Cuneiform Calculator (Ang, 2007), an interactive

[18] http://kadingirra.com/

calculator application using cuneiform numbers; and Write Like a Babylonian[19], an interactive application where the user can see their name written using cuneiform symbols.

Figure 11. Screen capture from the serious game for heritage "Discover Babylon"

A serious game for heritage where the player can navigate 3D environments of Mesopotamian cities and learn about the significance of Mesopotamia in world history (Escape Hatch Entertainment, 2007).

2.6. Experiential Concepts in Video Games

2.6.1. Summary of Relevant Concepts

There are a number of different concepts that are relevant to, and are used to describe, the experiences of interacting with virtual heritage, serious games, and video games in general. A summary of those concepts that are most relevant to the current project are given below.

Presence has been assigned many different definitions (Skarbez, Brooks, Jr. and Whitton, 2018), however in the context of interactions with virtual environments it is typically used to refer to an experience of "being there" (Steuer, 1992), a "psychological state where the

[19] https://www.penn.museum/cgi/cuneiform.php

virtuality of experience is unnoticed” (Lee, 2004), or the “perceptual illusion of non-mediation” (Lombard and Ditton, 2006). Authors have also argued that presence is a multi-faceted concept, involving spatial presence, involvement, and realness (Schubert, Friedmann and Regenbrecht, 2001). Presence has been used as an object of investigation for many past studies into virtual heritage and virtual museums (Devine, 2007; Sylaiou, Mania and Paliokas, 2013), serious games and virtual environments for learning (Bulu, 2012; Bachen *et al.*, 2016; Cho, 2018), as well as in commercial video games (McCreery *et al.*, 2013). Finally, research has also investigated the effect of first- and third-person perspectives in 3D games on presence and experienced sense of embodiment within virtual environments (Gorisse *et al.*, 2017).

Cultural presence refers to the extent to which a participant feels present within another culture, and has been applied to virtual heritage applications (Champion, 2006, 2018). It has been suggested that the concept comprises three factors; *cultural representation and engagement*, *social presence*, and *communicational aspects of technology* (Pujol-Tost, 2018). Guidelines have also been suggested for how to achieve a strong sense of cultural presence in virtual heritage applications (Pujol and Champion, 2012).

Sense of place is typically used to refer to the layers of interpretation, affect, and meaning that are applied to our physical surroundings, having been expressed as “place = space + meaning” (Harrison and Dourish, 1996). Authors have defined the concept as having cognitive, conative, and affective dimensions and have given recommendations for supporting each in virtual environments (Arora and Khazanchi, 2014). Sense of place is often closely related to presence (one could express it as the “there” in “being there”) and it has been argued that it is a factor of presence (Turner and Turner, 2006).

Immersion is a term understood differently in several contexts. The definition most relevant to this project is the one used within the context of video games, in which immersion refers to a very complex and multi-faceted concept closely related to presence, engagement, and flow, among others (Zhang, Perkis and Arndt, 2017). Nevertheless, it is also commonly used and understood by the commercial video game industry, including most players and games journalists. Several different definitions of immersion have been proposed (Brown and Cairns, 2004; Ermi and Mäyrä, 2007; Jennett *et al.*, 2008; Calleja, 2011) but no single one is used universally. It is also often proposed that immersion is strongly linked to presence, yet experimental evidence has shown that the two concepts can be entirely independent of one another (Cairns, Cox and Nordin, 2013). Some evidence has shown the positive impact of game immersion on learning in serious games (Cheng, She and Annetta, 2015). Finally, Zhang *et al.* (2017) also found that emotional forms of immersion are far more effective than spatial forms of immersion at giving users a sense of "being there".

Other relevant concepts include cognitive and affective empathy, which has been claimed to be an important aspect of serious games for heritage (Kidd, 2015) and changing people's attitudes towards other cultures (Huang and Tettegah, 2014); engagement with serious games (Hookham and Nesbitt, 2019), video games (Boyle *et al.*, 2012), and technology in general (O'Brien and Toms, 2008); enjoyment of media entertainment (Vorderer, Klimmt and Ritterfeld, 2004); and flow when playing games (Sweetser and Wyeth, 2005; Chen, 2007), which has also been shown to be an important factor of enjoyment and performance in game tasks (Weibel and Wissmath, 2011).

2.6.2. Measurement of Experiential Concepts

For each of the experiential concepts introduced in the previous section, different methods of measurement have been introduced and validated to different extents. The measurement of presence is a well-established field with countless applications. The most common approach is the use of a post-experience questionnaire to measure the level of presence experienced during the event, and many such questionnaires have been proposed (e.g. Slater, Usoh and Steed, 1994; Witmer and Singer, 1998; Lessiter *et al.*, 2001; van Baren and IJsselsteijn, 2004). Doubt has been cast over the power of some of these questionnaires to measure differences between real and virtual experiences (Usoh *et al.*, 2000), however they nevertheless persist as some of the most commonly utilised methods for measuring experiences in virtual environments. Cultural presence, however, despite its relevance to the history and heritage sector, is a far more recent concept and has not received such research interest. Accordingly, there are few validated instruments for measuring cultural presence.

There have also been some attempts to develop instruments to measure sense of place, but due to the close relationship between place and presence, some of these instruments actually directly utilise a presence questionnaire (Benyon *et al.*, 2006). Finally, some different approaches for measuring game immersion have been proposed, including self-evaluation questionnaires (Cheng, She and Annetta, 2015) and techniques based on physiological signals (Jennett *et al.*, 2008). Nevertheless, the level of validation and acceptance of these methods is somewhat low, likely compounded by the complex nature of, and lack of any universally accepted definition of, game immersion.

Therefore, it is concluded that when measuring user experience in a virtual environment, especially one for historical learning, presence is the soundest concept to measure, through application of post-experience questionnaires. This is due to the concept's wide acceptance and use within the virtual reality and serious games fields as well as its many well-validated instruments. Furthermore, presence has also been experimentally shown to influence flow, character identification, and empathy in serious games, which influences interest in learning (Bachen *et al.*, 2016).

2.7. Constrained Virtual Environments

2.7.1. Theory of Constrained Virtual Environments

Constrained virtual environments are a concept proposed by Turner *et al.* (2013), and they refer to virtual environments where the level of detail and fidelity has been intentionally reduced, but in such a way that the experience of place for the participant should be comparable with that of a virtual environment with a higher level of detail. This concept is built upon the theory of the tourist gaze (Urry, 2002), in which being a tourist means experiencing only a reduced, often stage-managed, set of highlights of a place. The tourist, however, can still achieve a strong sense of that place in a relatively short time, as their gaze is limited to viewpoints, attractions, and scenic lookouts, without requiring the exhaustive detail that comes with long-term exposure. Turner *et al.* (2005) argue that to experience a virtual environment for a short time is, in a sense, to be a tourist in that environment. They argue that a participant in a virtual environment could similarly be exposed to a reduced set of highlights and viewpoints, and still achieve a strong sense of place in that environment.

Turner *et al.* (2013) argue that when a participant is presented with a lower fidelity virtual environment, they simply cannot offload as much of the cognitive burden onto the environment and must make more extensive use of their own cognitive structures, leading to "strong" rather than "weak" mental representations. They also base these proposals on their theories of "digital make-believe" (Turner *et al.*, 2016), in which they suggest that to interact with a virtual environment is really a session of make-believing, in which we do not suspend our disbelief that we are there, but we are simply willing to pretend as though we were, and engage with it with the relevant mental schemata. In this way, Turner (2016) also proposes that make-believe can give an account of presence. Finally, parallels are also drawn between constrained environments and the book problem (Turner, 2014), which refers to the paradox whereby books and printed words are among the lowest fidelity forms of media available, yet are nevertheless capable of creating some of the most vivid and engrossing worlds for which readers have a powerful sense of place.

2.7.2. Implementation of Constrained Virtual Environments

Turner *et al.* (2013) implemented these theories and developed a constrained environment for giving a participant a tourist experience of the city of Edinburgh. The environment was made from several scenes, each representing a tourist gaze over a different part of the city, as shown in Figure 12. Each scene consisted of several photographic layers representing different objects within the view, layered with a parallax effect. As the user moves the cursor across the screen the layers move, and the layers of objects closer to the viewer move more, creating an illusion of depth. Furthermore, the authors made use of chiaroscuro, a technique using highly contrasting lighting to create a greater sense of depth in an otherwise 2D image (Turner, Turner and Carroll, 2005), and also replaced the photographic Edinburgh sky with a vividly coloured one, in a deliberate attempt to reduce the level of photorealism (Turner, Turner and Burrows, 2013).

Figure 12. A scene from a constrained environment of the city of Edinburgh

Reprinted, with permission, from Turner et al. (2013). © 2013 Inderscience.

The authors validated the environment experimentally (Turner, Turner and Burrows, 2013) and reported positive results, although they admitted they could not test the constrained environment against an equivalent 3D virtual environment. Another aspect not addressed by the authors is the capacity for constrained environments to transmit spatial information. Past work has focused on spatial cognition of users in 3D historical environments and their mental representations of these environments (Debailleux, Hismans and Duroisin, 2018), and it is yet unclear how this might differ in a constrained environment. Finally, Turner *et al.* (2013) argue that the greatest advantage of constrained environments is that they require greatly reduced resources to produce compared with an equivalent 3D environment, due to the lower levels of detail.

2.8. Discussion and Gaps in the Reviewed Literature

2.8.1. Serious Games Applied to the Field of Assyriology

As was described in Section 2.5, the first observed gap in the literature is that there have been very few examples of serious games for heritage presenting information or learning material on the field of Assyriology and Mesopotamian history, either presented in the serious games literature or otherwise, to the best of the author's knowledge. This therefore underscores the central aim and primary research question of the thesis, to investigate and explore how this field can be represented through serious games for heritage, in ways that support learning of, and create interest in, the field.

2.8.2. Definitions of Historical Content in Video Games

Through the review of different serious game for heritage projects in Section 2.5, it was recognised that there is a wide variety of different types of historical information that have been presented through serious games published in the literature. This includes information on tangible heritage such as physical artefacts, intangible heritage such as customs and beliefs, natural heritage such as landscapes, flora, and fauna, modern archaeological processes, historical events and processes, events of the natural world, as well as the personal stories of the individuals involved in all of these aspects. However, considering all the definitions of historical video games presented in Section 2.2, none of them are sufficient for describing these different types of historical and heritage content, nor the different ways that they can be presented through video games. This is primarily due to the fact that all of the definitions, both those found in the literature of serious games for heritage and historical game studies, only define these games as a whole unit, rather than attempting to describe them at a content level, and how each aspect of heritage and historical information is presented through the game's assets and mechanics. This, therefore, can be identified as the second gap in the literature.

2.8.3. Conceptual Frameworks for Serious Games for Heritage

The next literature gap relates to the conceptual frameworks and methodologies for designing serious games in general, and serious games for heritage in particular, detailed in Section 2.4. There have been many different frameworks presented throughout the literature, corresponding to different aspects of designing, developing, analysing, and evaluating serious games, and even some specifically developed for serious games for heritage. Nevertheless, none of these frameworks have comprehensively addressed the specific needs of serious games for heritage, especially the concept of meaningfully integrating play and learning, as was introduced in Section 1.3.3. Some of the reviewed frameworks for serious games partially address this issue, such as ATMSG (Carvalho, Bellotti, Berta, *et al.*, 2015) and the model introduced by Hall *et al.* (2014). However, neither framework is able to offer any insight into how historical instructional content could be embedded in the serious game in a way that supports player meaning-making. It is also not clear how such meaningful integration of play and learning might be achieved by examining the SGsH, and the design processes taken for each, reviewed in Section 2.5.

Furthermore, as was also observed by Roungas (2016) for serious games, many of the SGsH reviewed in Section 2.5, and referenced by the other reviews mentioned, were designed in a somewhat ad hoc manner. In many cases, the authors either did not use any framework for the design and development of the serious game for heritage (or did not disclose such use), or they simply created their own phases and processes for design and development, often without the level of research and validation effort that goes into the frameworks presented in Section 2.4.

This lack of willingness to utilise methodologies and procedures developed within the literature is somewhat concerning and is even exacerbated by the fact that many of these serious games for heritage are also never subjected to thorough analysis or evaluation.

2.8.4. Constrained Virtual Environments Applied to Serious Games for Heritage

The final observed literature gap relates to constrained virtual environments, and the fact that they have never been applied to serious games for heritage. Within this field, they could potentially bring many advantages due to the reduced resources required for their development and implementation, which is a concern for SGsH, as was discussed in Section 1.3.4. Additionally, the ability of virtual environments to replicate the experience of another time and place for the user is of critical importance in the history and heritage domains. Constrained virtual environments have also not been directly compared with equivalent 3D environments in comparative evaluation studies, to assess whether they can achieve a comparable replication of historical environments, as well as assessing their acceptance by users, their ease of use, and navigation within the virtual environment.

2.9. Conclusions

2.9.1. Literature Review Conclusions

In this chapter, a literature review has been conducted into the various topics that will be covered in this thesis. This included an introduction to the relevant bodies of literature, a background on history learning, a review of definitions of historical video games, a review of frameworks for the design, analysis, and evaluation of serious games, a review of frameworks for the design of virtual environments for historical learning, a review of serious game for heritage projects, a review of different experiential concepts relevant to video games and serious games, and how they can best be measured, and finally a review of the theories and implementation of constrained virtual environments.

Based on this review, gaps in the literature were identified. There have been very few examples of serious games presenting information on Assyriology, in academic literature or otherwise, which underscores the central research question of the project. Secondly, definitions of historical video games presented in the literature have only focused upon characteristics of games as a whole unit and are unable to describe different types of historical information, and how they can be represented through games at a content level. Next, while many frameworks for the design and analysis of serious games have been proposed, none have been identified which can thoroughly address the challenges unique to serious games for heritage, such as the meaningful integration of play and learning. Finally, constrained virtual environments present a promising approach for developing serious games for heritage, but have not yet been applied to this domain. Furthermore, constrained virtual environments have also not yet been evaluated against equivalent 3D environments in a comparative experimental study.

2.9.2. Statement of Research Questions

In Section 1.5.1, the primary research question of this project was defined as:

How can serious games be exploited, using limited development resources, to increase users' knowledge of and interest in Assyriology and Mesopotamian history?

Based upon the identified research gaps in the relevant academic literature, it is now possible to define a set of secondary research questions that provide a deeper exploration of the themes and issues identified by the primary research question, which will make significant additions to the literature and body of knowledge in this field. These secondary research questions are as follows:

Question 1. What model can be defined for how different types of history and cultural heritage information can be transmitted through a video game?

Question 2. How can serious games for Assyriology be implemented utilising constrained virtual environments, which are possible to realise with limited development resources?

Question 3. Can such constrained virtual environments still achieve a sense of place and presence, and can they still achieve their learning objectives?

Question 4. How can serious games be designed to present information on Assyriology and Mesopotamian history to users, which are appealing and engaging, but can also increase users' knowledge of and interest in the subject material?

2.9.3. Thesis Treatment of the Research Questions

Taken as a whole, this thesis will attempt to tackle the primary research question. It will do this by addressing each of the secondary research questions throughout its various chapters. The first of the secondary research questions will be addressed in Chapter 3, where a model for how different types of historical and heritage information can be presented through video games at a content level, will be presented and utilised. The second of the secondary research questions will be addressed in Chapter 4, where an Assyriology serious game engine and design will be proposed and developed, utilising a constrained virtual environment. This serious game for

Assyriology will then be evaluated directly against an equivalent 3D environment in an experiment in Chapter 5, to compare their ability to achieve a sense of presence and achieve their learning objectives, thereby addressing the third secondary research question. The fourth and final secondary research question will be addressed through Chapter 6, which will discuss the application of serious games to presenting the field of Assyriology and will propose a new methodology for designing and analysing serious games for heritage. The final secondary research question will also be addressed through Chapter 7, where the proposed methodology for serious games for heritage will be evaluated through a case study, involving the analysis and design of a serious game for Assyriology. The chapter will culminate in the development of a prototype game and a user-test to evaluate its capacity to be appealing and engaging, while also increasing users' knowledge of the subject material.

Chapter 3 A Model of Historical Content in Video Games

3.1. Introduction

3.1.1. Chapter Introduction

This chapter will address the first of the secondary research questions defined in Section 2.9.2, relating to a model to describe the historical or heritage information that is presented through historical video games, its characteristics, and which elements within the game systems are responsible for manifesting that information. This chapter will present such a model which defines this heritage or historical information, its associated learning outcomes, and its manifestation within the game. Furthermore, it will be shown how the model can describe content in both serious and commercial games, and how these manifestations of historical information often differ. The arrangement of the model and each constituent element will be described, and examples will be given from both SGsH and HCGs. It will then be shown how the model can be implemented to both advise the appropriate selection of historical content in serious games and to critically analyse content in historical commercial games, where learning outcomes are often not explicitly defined. The model will then be discussed in terms of its strengths and weaknesses.

3.1.2. Statement of Published Work

Much of the work detailed in this chapter, specifically parts 3.2, 3.3, and 3.4, were published in a conference paper (Hanes and Stone, 2017) and a journal paper (Hanes and Stone, 2018) with the current author as first author and the supervisor as co-author. Accordingly, there are some instances of reused images or text between these sections and the publications. It should be emphasised that the current author was responsible for the development of the work detailed in these publications, as well as writing the manuscripts, with the supervisor taking an advisory role.

3.2. A Model of Historical Content in Video Games

The following section details a proposed model to achieve the stated aim of describing how historical information and its associated learning outcomes can be manifested within the video game medium. First, the layout and each element of the model will be explained, and then a demonstration of the model will be given through examples in serious games for heritage and historical commercial games.

3.2.1. Explanation of the Model

The model of historical content in video games is based on the conceptual framework of serious games presented by Yusoff *et al.* (2009), selected due to its abstracted representation of any serious games, irrespective of field or application; its simplicity, being fully represented only through one diagram, shown in Figure 13; and also due to the authors having carried out some experimental validation of the framework using the Technology Acceptance Model (Yusoff, Crowder and Gilbert, 2010). The presented model of historical content is shown in Figure 14, and it expands some elements of the framework of Yusoff *et al.* (2009) and reduces others, where appropriate.

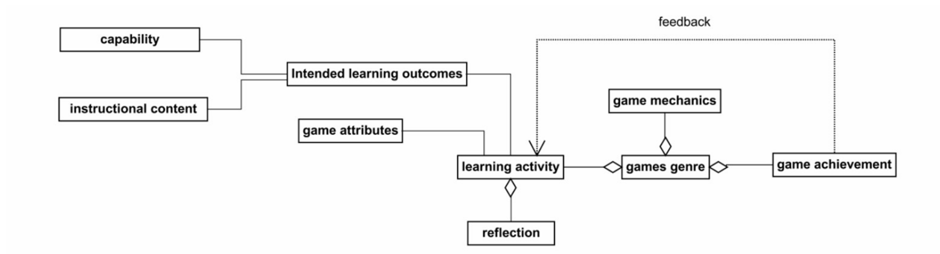


Figure 13. A conceptual framework of serious games

The diagram represents the component parts of any serious game. Reprinted, with permission, from Yusoff (2009). © 2009 IEEE.

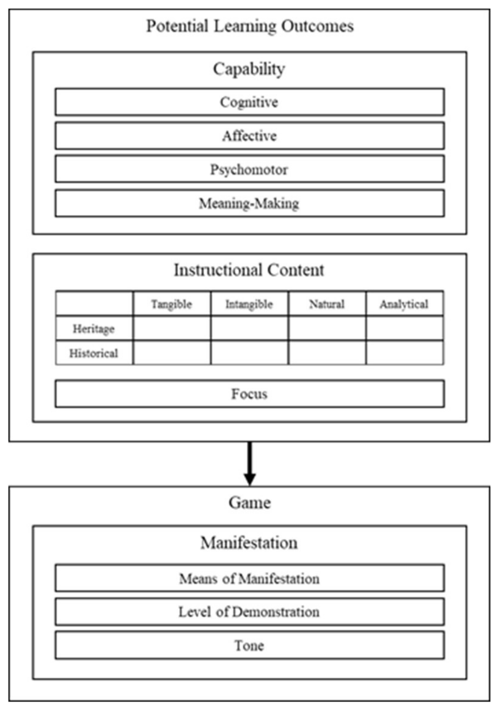


Figure 14. A model of historical content in video games

This proposed model represents heritage and historical instructional content and how it can be manifested within the video game format, as well as the properties of that manifestation and the associated learning outcomes. Adapted, with permission, from Hanes and Stone (2017). © 2017 IEEE.

a) Potential Learning Outcomes

This element of the model is equivalent to the "intended learning outcomes" element of the framework of Yusoff *et al.* (2009), however the subtle change of name reflects the fact that in commercial games for entertainment, learning outcomes may be inadvertently introduced without intention.

b) Learning Capability

This element of the model represents the nature of the skills, competences, or learning that are developed through playing the game. Yusoff *et al.* (2009) populated this element with the three aspects of Bloom’s Taxonomy, namely the cognitive (Bloom, 1956), affective (Krathwohl, Bloom and Masia, 1964), and psychomotor domains (Simpson, 1966). To this list we also add the theory of meaning-making (Silverman, 1993, 1995) due to its relevance to historical learning in video games, described in Section 1.3.2.

c) Instructional Content

This element represents the information that is presented through the game and is central to the learning activity.

i) Taxonomy of Instructional Content Types

The type of instructional content is defined by a two-dimensional taxonomy, where the first dimension differentiates between heritage and historical information, and the second differentiates between tangible, intangible, natural, and analytical information. Heritage information generally refers to “what existed” and historical information refers to “what happened”, and a more thorough explanation of each of the eight categories is shown in Table 4.

	Tangible	Intangible	Natural	Analytical
Heritage	Artefacts, constructions, and monuments	Languages, ceremonies, customs, and beliefs (UNESCO, 2003)	Landscapes, flora, and fauna	Historical and archaeological processes, research, and analysis conducted on tangible, intangible, and natural heritage
Historical	Historical events, processes, and actors	Personal emotions and reactions of historical actors	Natural events and processes	Historical and archaeological processes, research, and analysis conducted on tangible, intangible, and natural history

Table 4. A taxonomy of heritage and historical information types presented through video games

ii) Focus

This element refers to which aspects of the heritage or historical information are presented through the video game, which aspects are highlighted with attention drawn upon them, which are underemphasised, which are omitted entirely, and which are falsified, presenting inaccurate information. This concept was originally suggested by David Schaller (2014) by posing the question “what’s important about a sword?”, discussing the representation of swords in the HCG Assassin’s Creed IV: Black Flag (Ubisoft Montreal, 2013). The game is set in the age of sail and contains many highly detailed and historically accurate 3D models of swords which the player and enemies equip and fight with. However, aspects of these tangible heritage artefacts that a museum or cultural institution would typically be interested in presenting, such as its manufacture, aesthetics, and significance, are omitted. Instead, the game focuses on fictional attributes of the weapons, such as “speed” or “damage” which are meaningful only to the game’s combat systems, with no historical analogue. Such decisions are almost certainly taken for the sake of the entertainment value of the game, and it is observed that the focus of the information tends to be the key differentiating factor between historical information presented through serious games and commercial games.

Focus is therefore something that those wishing to repurpose HCGs for serious and educational purposes must be keenly aware of. Furthermore, there is an additional effect whereby focus can, if not controlled, dilute other content, because when accurate content is shown alongside inaccurate content with no markers to distinguish them, it is difficult for players to ascertain what is accurate or not. Some HCGs attempt to address this by relegating more accurate content to a different section of the game, for example an optional set of menus where interested players can read more about the content.

d) Manifestation

This element represents the manifestation within the game, through which the informational content is presented, which can take different forms and have many properties, what Chapman (2016, chap. 3) refers to as the "ludic aesthetics of historical description". Having reviewed many different SGsH and HCGs, these properties have been distilled down to three principle components – the "means of manifestation", the "level of demonstration", and the "tone" of manifestation.

i) Means of Manifestation

A. Verbal

The information is manifested as graphical text or aural speech, or both. This type of manifestation is commonly utilised within serious games for heritage, often due to its similarity with traditional forms of instruction, low development cost, and the wide range of complex concepts that can easily be shown and explained. This means of manifestation is most often presented as blocks of text in the UI, the speech of in-game characters, or narrating voice-overs.

B. Graphical

The information is manifested through visual means, which could be either photographic, 2D, or 3D, and either static or animated. This is another of the most commonly used means of manifestation, as games tend to be a dominantly visual medium. Graphical manifestation can help create games that are visually appealing and immediately recognisable to those familiar with the medium. However, graphical content can also be one of the most resource-intensive to produce, especially when attempting photorealistic 3D representations.

C. Aural

The information is manifested through sound effects and music, which can be an essential component of intangible heritage, however in many applications it is used only for game and environment ambience. Nevertheless, this can still form an important aspect of the virtual environment and the user's sense of presence within it (Serafi and Serafi, 2004).

D. Mechanical

The information is manifested through the game's mechanics and interactions. This is especially relevant when the information details a historical system or set of rules which the game mechanics aim to simulate. Past work has focused on the ability of serious games to teach the makeup and dynamics of systems through their simulation in the game mechanics, as well as highlighting the challenges of such approaches (Wasserman and Banks, 2017). Other work has focused on the potential for video games to simulate, and thereby also teach the player about, systems found within history and historical thinking (Bogost, 2005). Another relevant concept is that of procedural rhetoric, though this will be discussed separately in Section 3.5.2.

ii) Level of Demonstration

The extent to which the information is presented in a demonstrative, realistic, and literal way, or is presented as abstracted and metaphorical. Demonstrative manifestations may be used in an attempt to present the past as it was, or as close as is feasibly possible, whereas abstracted manifestations may be used to simplify unnecessary information, to hide certain aspects of the information, or simply as a visual aesthetic. The reason for utilising demonstrative or abstracted manifestations often depends upon the focus of the information; when macro-scale processes are focused upon rather than the actions of individual actors, it may make sense from a game design perspective to abstract and simplify the information presented. Abstraction may also be used to remove sensitive or inappropriate content, especially when the target audience are younger players.

iii) Tone

The use of affective tone and design for empathy in the manifestation of information is common within the historical domain. As Huang and Tettegah (2014) established, empathy is a critical factor in changing player's cultural attitudes in serious games, which is often an important aim of SGsH. Kidd (2015) has also studied the use of affective design in serious games for museums, suggesting guidelines for designing games to evoke cognitive empathy for affective learning.

3.2.2. Demonstration of the Model

To demonstrate the use of the model and its different elements for analysis of heritage and historical content, examples will be given from different SGsH and HCGs.

a) Cognitive Learning Outcomes for Tangible and Intangible Heritage Information

In the serious game for heritage "Discover Babylon" (Lucey-Roper, 2006; Escape Hatch Entertainment, 2007), which depicts virtual environments of ancient Mesopotamian cities, tangible heritage information is manifested through static 3D models throughout the environment depicting buildings such as ziggurats, temples, and markets, as well as objects and items typically found within those buildings. Intangible heritage information of the activities performed in those buildings and their social context is instead predominantly shown through a purely textual manifestation, shown after interacting with an information token in the environment, somewhat similar to receiving textual information to supplement the viewing of an artefact in a museum display.

In the SGH "Icura", which aims to raise interest and awareness in Japanese culture and etiquette, the authors state their intentions to maximise the use of constructivist learning principles (Froschauer *et al.*, 2010). Intangible heritage information is therefore manifested through both text and the game mechanics. For example, a character explains to the player through an in-game email that people must wear slippers when inside a Japanese temple. If the player is then to gain entry to the temple section of the 3D environment, they must interact with the slippers to put them on, else an NPC guard will refuse them access.

b) Psychomotor Learning Outcomes for Intangible Heritage Information

The SGH "i-Treasures" (Dagnino *et al.*, 2015) aims to teach players psychomotor learning outcomes for intangible heritage, such as folkloric dance, by manifesting the dance techniques through both animated 3D models of dancers and as 2D film footage of professionals performing them, as shown in Figure 15. The player must then imitate the techniques and, through sensors such as the Microsoft Kinect, the player's performance is rated and suggestions for improvement are provided.

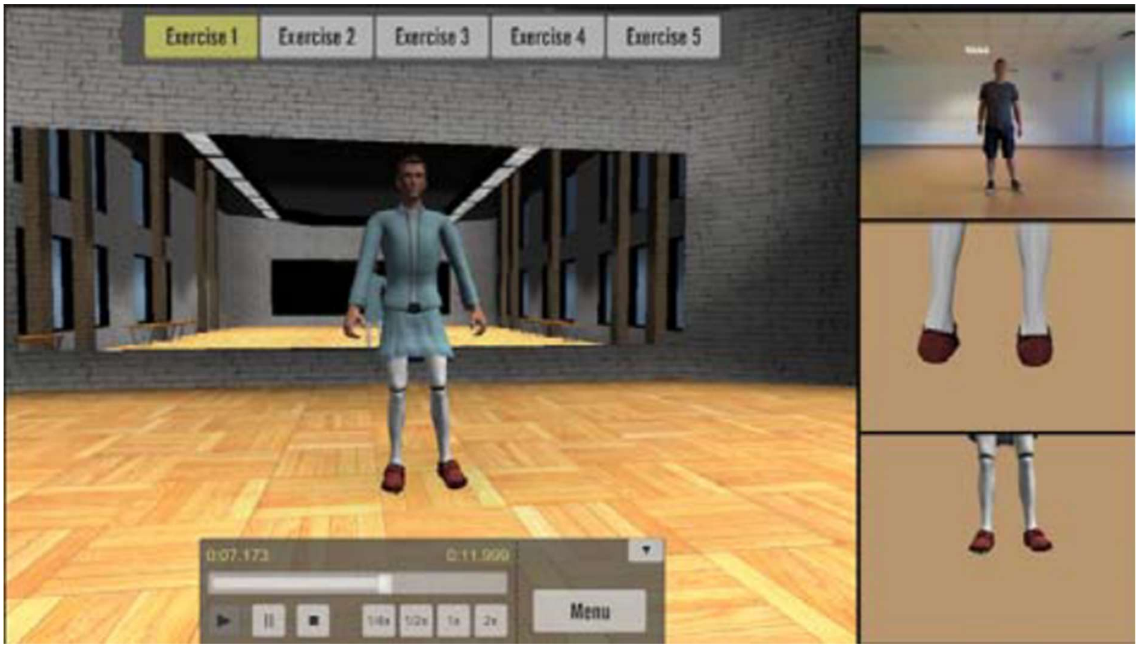


Figure 15. Screen capture from the serious game for heritage "i-Treasures"

This serious game aims to teach players psychomotor learning outcomes for intangible heritage. Reprinted from Dagnino et al. (2015). © 2015 IATED.

c) Manifestations of Natural Heritage Information

An example manifestation of natural heritage information can be found in the SGH "Fort Ross Virtual Warehouse" (Lercari *et al.*, 2013), which recreates the area of Fort Ross, California, through static 3D models of the surrounding landscapes, as shown in Figure 16.

Figure 16. Screen capture from the serious game for heritage "Fort Ross Virtual Warehouse"

This serious game represents natural heritage, such as the landscape surrounding Fort Ross, California. Reprinted, with permission, from Lercari et al. (2013). © 2013 IEEE.

d) Manifestations of Analytical Heritage Content

The SGH "Yrsum" (Gabellone *et al.*, 2017) depicts the landscape of a medieval Italian fort town which the player must reconstruct. Multispectral remote sensing images and LiDAR data collected from the real site of the town through archaeological analysis are manifested through 2D images and 3D models, respectively, to aid the player in deducing where each building was situated.

In the "Writing Challenge" SGH in the British Museum Mesopotamia game collection (The British Museum, 2006c), the player takes on the role of a young assistant to an Assyriologist and must perform the modern archaeological activity of reconstructing cuneiform tablet fragments, manifested through the game mechanics. The tablets themselves are manifested as 2D photographs with textual clues for the inscribed text, and the player must learn to use the information available, the colour and patterns of the tablets as well as the subject of the text, to find joining fragments.

e) Instructional Content Focus

As described earlier, "Assassin's Creed IV: Black Flag" (Ubisoft Montreal, 2013) contains examples of heritage content where the focus serves the entertainment gameplay experience rather than the cultural heritage itself. Many further examples can be found from within other games in the series, for example there are many accurate manifestations of architectural heritage, such as the Piazza del Duomo in Florence, Italy, represented in "Assassin's Creed II" (Ubisoft Montreal, 2009), however the focus of this manifestation is primarily on how the buildings can be climbed up by the game's protagonist. An example of a similar focus applied to historical events is shown in the third game in the series (Ubisoft Montreal, 2012), where the player is party to some of the historical events leading to the American declaration of independence and subsequent war, involving many of the key historical actors. However, the focus mixes these actors and events with a fictional storyline that twists and obfuscates their real historical significance.

f) Abstracted Manifestations of Historical Information

In the historical biographical SGH "The Cat and the Coup" (ValaNejad and Brinson, 2011), events from the life of the Iranian Prime Minister Mohammad Mossadegh are shown through a surrealist collage of Persian art. The enaction of each event and the involvement of historical actors and foreign powers are manifested in a highly abstracted form. For example, when the Iranian Shah, UK, and USA played a part in the events, they are shown as abstracted 2D animals within the collage, as shown in Figure 17.

Figure 17. Screen capture from the serious game for heritage "The Cat and the Coup"

The Cat and the Coup (ValaNejad and Brinson, 2011) is a serious game for heritage giving details on the life of Iranian Prime Minister Mohammad Mossadegh through surrealist collages of Persian art. Here, the influence of the US, UK, and Iranian Shah on the depicted events are shown as abstracted animals (a lizard, bulldog, and peacock, respectively). © 2018 Kurosh ValaNejad and Peter Brinson.

In the SGH "Battle of Thermopylae" (Christopoulos *et al.*, 2011), the violent and horrific end to the battle is shown through abstracted 2D line drawings, akin to the final pages of a fairy-tale with a grim ending. In an SGH telling the story of a Jewish girl escaping central Europe with her family during WWII (Moffat and Shapiro, 2015), the player must make choices of what the family should do. If the player makes an incorrect choice, the fatal consequences are shown through an abstracted and sensitive manifestation, for example the family home slowly catching fire, proceeded by a "game over" screen if the player incorrectly chooses not to leave.

g) Affective and Factual Tones for Affective Learning Outcomes

Within serious games for heritage, different approaches have been observed for achieving affective learning outcomes, utilising a variety of different tones. As Kidd (2015) details, the

Canadian War Museum's SGH "Over the Top"[20], an adventure game focusing on Canadian soldiers in WWI, manifests the emotional toll that the death of soldiers had on their friends and families (a piece of intangible historical information) with a highly affective tone. The game achieves this by asking the user to input their own name and the name of their best friend. When the player chooses a wrong option and receives a "game over", a military letter with the player's name printed on it, notifying the parents of their son or daughter's death in the war, is shown. Furthermore, the name of the player's friend is assigned to one of the characters, who ultimately dies in the story, shown through 2D animated cutscenes and text.

Conversely, the SGH "High Tea" (Birchall and Henson, 2011) manifests the affective learning outcome of the immorality of British Opium trade in China in the 19th Century, through the game's text and mechanics, but with a highly factual tone that does not explicitly mention the implications of the player's actions. This realisation and subsequent affective learning are left to the player to make through their own reflections.

3.3. Appropriate Selection of Historical Content in Serious Games

The first of the stated aims of the model of historical content in video games is to aid designers of SGsH to select and implement appropriate manifestations of heritage and historical information with appropriate characteristics for the given learning outcomes. An appropriate manifestation is one that that sufficiently affords and supports the intended learning outcomes

[20] https://www.warmuseum.ca/overthetop/

for the target user group, within the target context of usage, while also achieving the desired gameplay experiences within the given development budgets and limitations.

Each of the examples of serious games for heritage given in the previous section utilises manifestations of information that are appropriate to their given learning objectives and desired gameplay experience. Discover Babylon (Lucey-Roper, 2006) aims to increase general awareness and interest in Mesopotamian civilisations by presenting the player with buildings and structures from the period, allowing the player to navigate them in 3D using their avatar. It was decided, perhaps due to budgetary demands, that manifestation of the activities within those buildings and environments must take a lower priority, and they were simply presented through short textual descriptions. Icura (Froschauer *et al.*, 2010) aims to teach players about Japanese culture and etiquette, which could have been sufficiently manifested only through the text of the in-game helper agent, however the developers stated they wanted the player to be more constructively involved in the learning process, hence their decision to also manifest some of the heritage information through the game mechanics. i-Treasures (Dagnino *et al.*, 2015) must manifest the various dance steps and techniques in sufficient high-fidelity and detail, such that the player is able to learn the intricacies of the movements as well as their emotional content and heritage significance. It was therefore decided that both high-quality 3D animations and video footage of a professional performer were required to achieve this demand. One of the stated aims of High Tea (Birchall and Henson, 2011) was that it should be able to achieve its affective learning outcomes of the immorality of the player's actions, without being readily identifiable as an educational game. The factual and rather non-affective manifestation of information in the game's 2D graphics, text, and mechanics means that the game could easily be mistaken for a pure entertainment experience, however enough hints are given that many players did indeed achieve the learning outcome through their own reflection.

Finally, Yrsum (Gabellone *et al.*, 2017) emphasises its use of real-world data from different archaeological analysis processes. As such, the manifestation of information in the game was perhaps most dictated by the natural form of each dataset. The LiDAR analysis results were in the form of a 3D model and the multispectral remote sensing results were in the form of a 2D map, so these datasets were manifested without modification, and the game mechanics were then built around them.

3.4. Critical Analysis of Historical Content in Historical Commercial Games

McCall (2016) states that if educators wish to utilise video games in history lessons, especially COTS games, they must first have a detailed knowledge of the content of the game, especially where the game is strong or weak at "simulating the history", yet he offers no practicable guidelines for how to go about this. Similarly, Watson *et al.* (2011) describe the successful use of games in history classes, stressing the importance of identifying games with suitable content and "teachable moments". It is proposed that the presented model of historical content in video games represents a feasible approach for such critical analysis.

Such an approach will now be demonstrated for the historical commercial game "Valiant Hearts: The Great War" (Ubisoft Montpellier, 2014), a 2D single-player puzzle-adventure game set during the First World War, where the player must navigate environments and solve puzzles to progress the story of several inter-related characters who are all caught up in the conflict in different ways. This game was selected because it elegantly demonstrates many different aspects of the model of historical content, while being suitable for younger audiences, with a 12+ PEGI rating[21], and receiving an average review score of 77% from 48 critic reviews on the critic aggregator website Metacritic (2014). Furthermore, the game has also been the subject of other attempts to describe its historical learning value, however such attempts did not provide suitable means for thoroughly evaluating the game's content in terms of its learning outcomes and its "teachable moments" (Anderson, 2019). The game's levels take place in different historically important locations during the war and the story is mostly told through 2D animated cutscenes between each level, all shown through a cartoon art style, shown in Figure 18.

The game also contains two menus labelled "historical facts", one for "facts" detailing the historical events and processes represented in the game, and one for "items" detailing heritage objects encountered. It is clearly intended that the content in each level is simplified and not historically accurate, whereas these menus attempt to be more historically robust, featuring text similar to what one might find in a museum and the logos of the partner organisations; "Mission Centenaire 14-18" (Zimet, 2013), a WWI centenary program, and Apocalypse World War 1 (Arnaud, 2014), an historical documentary series. This approach is similar to that described in Section 3.2.1, where the separation of content between levels and menus reduces the dilution effect if all of the content were mixed together.

[21] https://pegi.info/

Figure 18. Screen captures from "Valiant Hearts"

a) the "facts" section of the "historical facts" menu; b) the "items" section of the "historical facts" menu; c) the cutscenes presenting the game narrative; d) the gameplay. Adapted from Ubisoft (2014).

Table 5 shows an enumeration of the heritage and historical information manifested within the first level of the game and the characteristics of those manifestations. It is proposed that such an approach should be the first step of an educator wishing to analyse such a game for its suitability for inclusion in an educational context, and how its content should best be exploited for the intended learning outcomes. Of course, use of such games should also follow the best practices outlined throughout the literature for implementation (McCall, 2016) and evaluation (Connolly, T. M., Stansfield, M. H., & Hainey, 2008; Hainey, Connolly and Boyle, 2010).

Informational Content	Capability	Information Type	Focus	Manifestation	Means of Manifestation	Level of Demonstratio n	Tone
Assorted artefacts	Cognitive	Tangible heritage	Usually the appearance, use, manufacture, or history of the artefact are described. The information is similar to what might be shown in a museum display.	The "items" section of the "historical facts" menu. In each level, there are several artefacts hidden in the game world. When they are found, they are revealed in the items section.	Simplified 2D cartoon artwork and text	Somewhat abstracted art style	Factual
The events of the outbreak of WWI	Cognitive	Tangible historical	The key historical moments after the assassination of Franz Ferdinand to the outbreak of war are detailed.	Shown in the opening cutscene that introduces the player to the game.	Simplified 2D cartoon animations	Somewhat abstracted art style	Factual
				Shown as a " fact" in the historical facts menu, in a manner similar to what might be shown in a museum display.	A photograph and text	Demonstrative	Factual
The splitting of families due to the outbreak of war	Cognitive and affective	Tangible historical and intangible historical	The fact that families were split due to being from mixed nations or forced to enlist due to conscription. The emotional turmoil and uncertainty for the affected families is focused on.	Shown in the opening cutscene that introduces the game's narrative.	Simplified 2D cartoon animations	Somewhat abstracted art style	Highly affective and dramatic
				Shown through diary entries that present the thoughts and feelings of each character as the narrative unfolds.	Text in diary entry format	Demonstrative through 1st person writing style	Affective
Troop barracks and training process	Cognitive	Tangible historical	Only the appearance and atmosphere of the barracks is focused on. The infantry training process is simplified and used as the game tutorial.	Shown as a level in the gameplay, with corresponding backgrounds and props, and used as the tutorial level to teach the player the controls. Also shown in the historical facts menu.	Simplified 2D cartoon graphics and gameplay mechanics and goals	Somewhat abstracted art style	Somewhat affective within game narrative
The organisation and logistics of armies in WWI	Cognitive	Tangible historical	The organisation of soldiers into battalions, companies, and platoons is focused on, as well as the initial deployment of the British army.	Shown as a " fact" in the historical facts menu, in a manner similar to what might be shown in a museum display.	A photograph and text	Demonstrative	Factual
Military uniforms and equipment	Cognitive	Tangible heritage	Only the appearance, and some inaccurate use of equipment, is shown (e.g. throwing grenades is used as a core mechanic for solving puzzles).	The appearance of characters is defined by their military uniform. Throwing grenades is used as a core game mechanic for solving puzzles and progressing.	Simplified 2D cartoon graphics and game core mechanics	Somewhat abstracted art style	Factual
The use of railways for armies during WWI	Cognitive	Tangible historical	Only the appearance and atmosphere of the railway station is focused on.	Used as the setting for one of the levels, by being populated with puzzles the player must solve. Also shown in the historical facts menu.	Simplified 2D cartoon graphics and puzzles	Somewhat abstracted art style	Somewhat affective within game narrative
			The use of railways for mobilising and supplying troops is focused on, as well as the British use of railways and their efforts to build new rail lines.	Shown as a " fact" in the historical facts menu, in a manner similar to what might be shown in a museum display.	A photograph and text	Demonstrative	Factual

Table 5. An enumeration of historical content in Valiant Hearts: The Great War

The enumerated content is found within the first level of the game and was compiled using the proposed model of historical content in video games. Reprinted from Hanes and Stone (2018).

3.5. Discussion of the Model of Historical Content

3.5.1. Strengths and Limitations of the Proposed Model

One of the expected strengths of the proposed model is that it allows researchers and experts to talk about all of the different game types shown in Figure 4 using the same "vocabulary" and, as such, compare, contrast, and even combine them. Even though historical and heritage content in commercial entertainment games may, on the surface, appear very different from that presented through serious games, the presented model gives insight into how and why these differences occur, especially through the focus element, and where and how the content can be similar. This means that the genre or type of game, the intentions of the developer, and the methods employed in its design are less relevant, what is important instead is the actual content in the game, the elements that are viewed, created, and interacted with through the act of playing. With this focus on the content of the game, rather than its high-level characteristics, educators are in a better position to consider how content initially created for entertainment can be reused for serious purposes, as has already been shown in Section 3.4. A model that can see past the categorisations of "games for entertainment" and "games for education" is increasingly important as more educators and cultural institutions look to the games that people are already playing to help engage them, and as more commercial game developers look to find new uses for the wealth of research and informational content that goes into their games, for example the "Discovery Tour Mode" in "Assassin's Creed Origins" (Ubisoft Entertainment SA, 2018).

Next, the proposed model gives insights to SGH designers regarding the different ways in which they can manifest given heritage or historical information into the game. This allows them to enumerate the many possible characteristics of the manifestation, consider the effects.

advantages, and disadvantages of each, and make more informed choices for the design process.

Finally, the model allows analysis and consideration of each component of the game in question in separate isolation, which may be advantageous when considering learning outcomes and what a player will learn when encountering a certain subset of content within the game. This will naturally also make the process of evaluation of learning easier, especially when such evaluations are performed through non-disruptive measurement of game performance and game completion (Serrano-Laguna *et al.*, 2018).

However, a counterpoint to the above strength, and the first limitation of the proposed model, is that it takes a rather low-level approach and is unable to describe the complex interrelationships between each component of game content. Relating to Chapman's (2016, p. 16) definition of heritage video games, the model may be strong at describing games "that in some way represent the past" but less strong at describing games that "relate to discourses about [the past]". It simply does not define the high-level characteristics of the game such as themes, patterns, or discourses.

Another limitation of the model is that it does not give any insight into the mechanisms through which the game content and mechanics lead to learning outcomes being achieved, nor how effective the game is at achieving them. The model is more of a tool for describing the game itself than the interactions that take place when it is played by a user. As such, this deficit can be overcome by using other frameworks or models of serious games in parallel that are able to describe these player-game interactions, such as ATMSG (Carvalho, Bellotti, Berta, *et al.*, 2015) or LM-GM (Arnab *et al.*, 2015).

Finally, while the model allows a designer of serious games for heritage to enumerate the possible ways of manifesting particular heritage or historical information in the game, it does not offer a prescribed methodology nor set of practicable guidelines for the best ways to achieve this. However, this will be partially addressed in Chapter 6, where the model will be developed into a methodology for designing SGsH that achieve a meaningful integration of play and learning and connect players with historical activities.

3.5.2. The Role of Procedural Rhetoric

As was alluded to in Section 3.2.1, one interesting aspect of manifesting heritage and historical content through a game's mechanics is the potential of procedural rhetoric. Procedural rhetoric is a concept most attributed to Ian Bogost (2007, 2008) and refers to the capacity of video games to both transmit information and also to persuade users through their mechanics and rules. Procedurality refers to the systemic aspect of video games; the systems and dynamics that a player explores by interacting with the game through play. Bogost argues that procedurality is like any other form of transmission of information and can be used for rhetorical purposes. For example, when someone plays the historical strategy game Victoria II (Paradox Development Studio, 2010), which focuses on geopolitical strategy during the 19th and 20th Centuries, players will quickly learn through experimental play that the most successful strategy for a European power, as defined by the game rules and balancing, is not to oppose their neighbours, who pose too much of a challenge, but to colonise and exploit smaller nations across the world who own many valuable resources but lack the capacity to fight back as effectively. Bogost would argue that, whether the developers intended it or not, the player has learned about, even been persuaded of, the nature of geopolitics from that period through the procedural rhetoric contained within the game.

While Bogost (2007) argues that procedural rhetoric is a means of making arguments and persuading the player to take on a particular point of view, it could also be very relevant to serious games for heritage, as a means for the designers to analyse and control the argument that the serious game inherently makes through its rules and mechanics. This might then allow a better understanding and careful control of accuracy, authenticity, and bias inherent in the informational content that the serious game is presenting. Furthermore, this approach may also lead to a better integration of play and learning in serious games for heritage, due to the greater insight the approach gives into how information can be embedded in the game's mechanics, which the player must interact with to uncover and learn. One aspect of heritage and historical information that might be most appropriate for presenting through such an approach is the representation and understanding of the world from a historical agent's frame of understanding and world-view. An SGH could be designed, such that the game rules and mechanics embody the beliefs of the actor that the user takes the role of. This could then lead to a greater level of cultural presence and understanding of that historical actor and the cultural context in which they lived.

However, there are some serious issues with the proposed approach. Procedural rhetoric has had a strong following in the serious games and game design community, however this has mostly been from the approach of "persuasive games" (Ferrara, 2013; Siriaraya *et al.*, 2018), which aim to persuade users to change their beliefs, attitudes, or behaviours. Even Bogost (2007) himself argues that serious games are actually just persuasive games. Such persuasive games clearly make full use of the rhetorical nature of procedurality, however it is not at all clear how one might use those same tools to design games that intentionally reduce their level of bias and persuasion, a sort of procedural "non-rhetoric" that aims to increase understanding without persuading for a particular point of view. Indeed, Champion (2015, pp. 36–38) raised similar concerns, stating that "when I consider the application of procedural rhetoric to interactive history and to virtual heritage, I am also perplexed as to where and how I could usefully leverage these theories", arguing for a simpler theory to be developed instead.

Furthermore, there are also some deep criticisms of procedurality and procedural rhetoric itself. Sicart (2011) attacked the theories for not considering player agency and treating gameplay as a one-way transfer of information from game to player, rather than a dialogic interaction. This point is particularly relevant to learning in history, given that the field has progressed in the last 60 years from a paradigm of humans as "passive receptacles waiting to be filled with culture" (Rounds, 1999) to one of constructivism and meaning-making. Procedural rhetoric could threaten to move backwards to once again treating players as "receptacles to be filled" or as crowds to be persuaded.

Finally, there are issues with the technical feasibility of developing serious games according to this approach. Designing entire sets of rules and game mechanics is a highly challenging and resource-intensive process, making it a rather inefficient means of manifesting information in a serious game. As was discussed in Section 3.3, there are other, more efficient ways of manifesting information in video games which may be necessitated by the budgets and limitations of serious game development.

3.6. Conclusions

3.6.1. Chapter Conclusions

In this chapter, a model of historical content in video games was proposed to describe what heritage and historical information can be presented through video games, what learning outcomes they can afford, and how the information can be manifested in the game, to address the first secondary research question of the project. The model also described how, through a different focus on the source information, manifestations in commercial games tend to differ from those in serious games. Each element of the model was explained and several examples of different manifestations of content in SGsH and HCGs were described. The application of the model to both the selection of content in serious games for heritage and to the critical analysis of content in historical commercial games was described and demonstrated. Finally, strengths and limitations of the model were discussed, as well as its relations to the theories of procedural rhetoric in SGH design. The proposed model represents a new way of looking at historical video games at a content-level that offers new insights into designing and analysing these games, and the learning they afford.

3.6.2. Future Work

Future work in this research direction includes further application of the model to cases of the design of serious games for heritage and to the analysis of content in historical commercial games. The results and feedback from this work can help to further refine the proposed model, adding more detail or even more elements, where it helps to better provide insight for these design and analysis processes and improve the applicability of the model.

3.6.3. Applications to the Thesis

The proposed model will also be used to create insights into serious games for heritage throughout the rest of the thesis. In Chapter 4 the model will be used to help define and describe what a constrained virtual environment is in a serious game for heritage, in terms of its content, and how the format might affect the nature of information manifested in the game and the characteristics of those manifestations. In Chapter 6 the model will be further developed, utilising activity theory and the concept of activity context bridging, into a practicable methodology for designing and analysing serious games for heritage that achieve a meaningful integration of play and learning.

Chapter 4 Constrained Virtual Environments Applied to Serious Games for Heritage

4.1. Introduction

4.1.1. Chapter Introduction

This chapter address the second secondary research question, defined in Section 2.9.2, relating to how serious games for heritage can utilise constrained virtual environments, to help reduce the resources required for their development. It will build upon the literature identified in Section 2.7, relating to the theories, development, and implementation of constrained virtual environments, and will discuss the feasibility of applying such environments to serious games for heritage, including the design of navigable and interactive environments to support history learning. The development of a game engine that supports serious games for heritage utilising constrained virtual environments will then be described, including the software architecture and features of the engine, relating to environments, game mechanics, interactions, and content production. Next, the implementation of one of the levels from the SGH Discover Babylon (Escape Hatch Entertainment, 2007) in the game engine will be described, including its navigable environment, interactions, narrative elements, and its informational and learning content. Finally, the application of constrained virtual environments to serious games for heritage will be discussed, including the practical limits and boundaries of the theories supporting constrained environments and lessons that can be learned from the commercial video games industry. The challenges and opportunities of applying constrained virtual environments to serious games for heritage, and the implications on the manifestation of historical content and the meaningful integration of play and learning in SGsH, will also be discussed.

The SGH Discover Babylon was selected as a case study for applying the theories of constrained virtual environments for three reasons. Firstly, it is one of the only examples of a serious game for heritage applied to the field of Assyriology that aims to be a full gaming experience, comparable with that offered by commercial games, including 3D graphics, several hours of fun and engaging gameplay, and pedagogical content supporting explicit learning outcomes (Lucey-Roper, 2006). Secondly, due to the reported issues the game development process had with budgets (Crewdson, 2007), Discover Babylon could have greatly benefited from the potential reductions in required resources offered by constrained virtual environments, which perhaps could have allowed the completion of the intended game within the allotted budget. Although the game is now over 10 years old, this challenge has arguably gotten even more difficult given advances in the state-of-the-art in 3D and gaming technology. Finally, the nature of the game itself makes it ideal for presentation through constrained virtual environments, including navigable 3D virtual environments depicting sites of historical significance, interactive NPCs and objects within the environment, simple but engaging "adventure game" mechanics that will be familiar to many players, and a narrative presented through simple cutscenes and sequences of character dialogue.

4.1.2. Statement of Published Work

Some of the work detailed in this chapter, specifically Sections 4.3 and 4.4, relating to the development of a constrained environment implementation of Discover Babylon, was published in a journal paper (Hanes and Stone, 2019) with the current author as first author and the supervisor as co-author. Accordingly, there are some instances of reused images or text between these sections and the publication. It should be emphasised that the current author was responsible for the development of the work detailed in this publication, as well as writing the manuscript, with the supervisor taking an advisory role.

4.2. Approach for the Application of Constrained Virtual Environments to Serious Games for Heritage

It is proposed that the initial approach for applying constrained environments to serious games for heritage should aim to transfer the elements and systems that already exist in SGsH directly into the constrained environment format, with as little modification as possible. This approach will be taken for two reasons; firstly, because it allows a more direct and scientific comparison between a traditional SGH implemented using a 3D virtual environment and a re-implementation of the same game with a constrained environment, where the only variable is the environment type. Secondly, because constrained virtual environments are still at a very early and immature stage of research, therefore it is advisable to begin by utilising design approaches already established and developed in 3D SGsH. Once the approach reaches a higher level of maturity and has been experimentally validated, new paradigms and design approaches can be developed and implemented to make better use of the opportunities afforded by constrained virtual environments and to better overcome their challenges and limitations. Indeed, in Chapter 5, an initial set of guidelines will be proposed for the design and implementation of constrained virtual environments for serious games for heritage, to be utilised and further developed by other researchers and in future work.

4.3. Development of a Constrained Virtual Environment Game Engine for Serious Games for Heritage

A game engine was designed and developed to support the implementation of serious games for heritage utilising constrained virtual environments that allow the implementation of the levels of Discover Babylon. The software system architecture and features of the game engine are described in the following sections. Although a bespoke engine was produced to ensure all the required features could be implemented, it would also be possible to develop constrained environments with an off-the-shelf game engine. In this case, the most important feature required of such an engine would be the development and application of custom graphics shaders.

4.3.1. Constrained Virtual Environment Game Engine Architecture

The game engine is based upon the XNA Game Studio platform (Microsoft Corporation, 2011) and is written in C#. This platform was chosen for two reasons. Firstly, it allows all of the required engine features which will be described in Section 4.3.2, including advanced graphics and shaders. Secondly, the author has extensive experience using this platform, which expedited the development of the engine and allowed its completion within the time restrictions of the project. The software system architecture for the developed game engine is shown in Figure 19 and comprises the following principal elements.

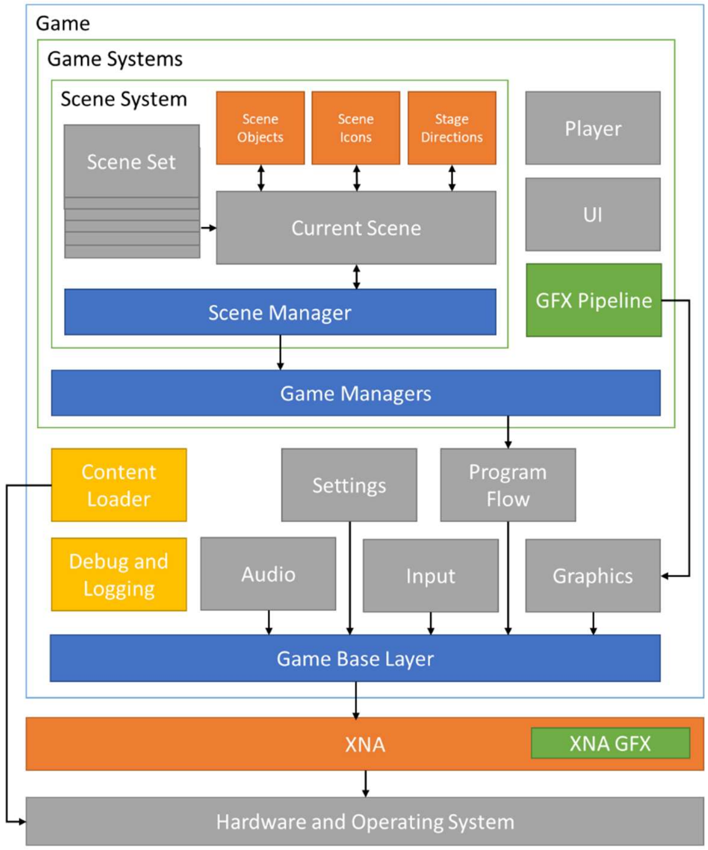


Figure 19. Software architecture diagram for the developed constrained environment game engine

The diagram shows the different layers and aspects of the developed game engine to achieve the required game systems and mechanics within constrained virtual environments. Also shown is the interrelations of the components and how the engine interacts with the hardware through the XNA platform.

a) Hardware and Operating System and XNA Layers

These layers represent the actual computer hardware and Windows operating system that the game is running on, as well as the XNA libraries which, through the form of several "*.dll" libraries, allow a program access to functionality that is useful in games, such as update and graphics loops, as well as direct access to the graphics hardware installed in the computer for efficient rendering.

b) Game

This system represents the game executable that runs on the user's computer. It consists of a base layer allowing communication with the XNA layer and use of its functionality, as well as several modules which are each responsible for core game functionality. All the content that is specific to the implemented SGH is loaded through the content loader in the form of texture, sound, shader, and XML files. Therefore, the game engine is self-contained and separated from the content, so that the content can be designed and implemented without having to compile or alter the engine source code.

c) Game Systems

The game systems represent the core game logic and presentation that players experience and interact with. At its core is a hierarchical set of game managers, each responsible for a different component of the game system, such as the player with their current states and inventory of items, the game UI, the graphics pipeline, and the scene system. The graphics pipeline also includes the option of post-processing filters, which are applied through shaders to the rendering of the entire environment.

d) Scene System

The scene system is perhaps the most fundamental aspect of the game systems, in that it supports all the required features of constrained virtual environments for SGsH. Central to this system is the concept of scenes, as described by Turner *et al.* (2013), where each scene represents a different view of the depicted environment, and each is equivalent to a tourist gaze (Turner, Turner and Carroll, 2005). However, scenes can also be used for cutscenes for exposition of the narrative, for puzzle sequences, or other various uses. There is a set of different scenes that together make up the game, which are loaded from the computer's storage through the content loader module. One of the scenes is the "current scene", which is rendered and interacted with. Each scene is made up of a set of scene objects, which can be static visual elements, animated visual elements, or interactive objects that exhibit certain behaviours when certain events are triggered. Each scene also contains a set of scene icons, which are buttons that can trigger certain events and behaviours when clicked with the mouse or tapped with a touch screen. Finally, scenes, scene objects, and scene icons can all utilise stage directions, which are used to underpin all the logical and dynamic behaviours within the scenes, such as changing the state of scene objects or transitioning to a different scene.

4.3.2. Constrained Virtual Environment Game Engine Features

Figure 20 shows screen captures from a demo scene implemented in the game engine to demonstrate some of its features. The scene consists of a cursor (shown as a red cross), moved with the computer mouse or touch screen, three static objects (shown as coloured squares), and an interactive icon (shown as a white circle with an "i" symbol). The static objects and icon each have a 2D position in the scene and a depth value between 0 and 1, representing the distance of the object from the camera.

As shown in Figure 20, as the cursor is moved across the screen, the rendered positions of the objects shift, depending on their depth value; objects closer to the camera move more than distant objects. This parallax effect was implemented and described in the original constrained virtual environment application by Turner *et al.* (2013) and helps to enhance the illusion of a 3D scene. To further enhance this illusion, a depth-of-field effect was added, not present in the application described by Turner *et al.* (2013). The depths of each object in the scene are used to create a depth map of the scene at each update loop, and the depth value stored in the depth map at the position of the cursor is sampled. Parts of the scene with a depth similar to the depth at the cursor will be in focus, and parts with dissimilar depths will be out of focus, the out-of-focus visual affect being achieved using a Gaussian blur effect. This functionality is shown through the smaller grey-scale images in Figure 20.

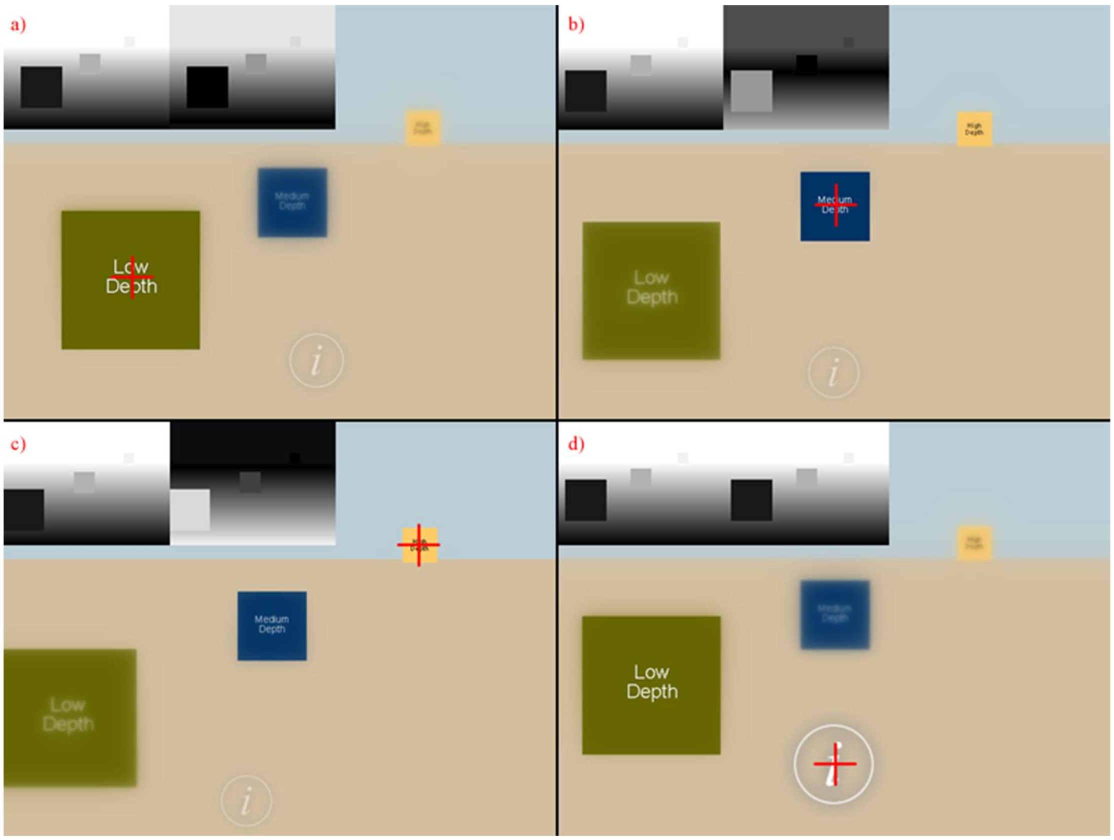


Figure 20. Screen captures of a demo scene in the developed game engine

Each image shows the scene, including 3 static objects at different depths (coloured squares), an icon at zero depth (white circle with "i" symbol), and the cursor (red cross). Overlaid over each image are a depth map on the left (black shows parts of the image at low depth, and white parts at high depth) and a focus map on the right (black shows parts of the image in clear focus, and white parts out of focus). Each image shows the cursor placed over different parts of the scene, shifting the parallax and focus effects.

4.4. Implementation of an Assyriology Serious Game in the Game Engine

4.4.1. Base Assyriology Serious Game

Two versions of the SGH Discover Babylon (Escape Hatch Entertainment, 2007) were released; a short "kiosk" version and a longer, more involved "full-game" version (Lucey-Roper, 2006). In the full-game version, the player travels back in time to different locations and periods within ancient Mesopotamia and takes on the role of different historical actors. Each location utilises a 3D environment representing a Mesopotamian city, which the player can navigate and explore with their avatar, viewed from a third-person perspective. The player must engage in dialogue with historical characters, trade goods, explore, and solve puzzles to unlock the next section of the game and unfold the developing narrative. The game utilises a very limited set of sound effects, used mainly for character dialogue, footsteps, when the player completes an objective, or when interacting with the UI. The environments themselves, however, contain almost no sound effects or music.

Each level also contains ten information tokens, which are shown as glowing icons hovering in the environment. When the player moves their avatar into the icon, an information message is shown, presenting an historical fact about the area of the environment the token was found in, often describing the activities that would have been performed there. The player is also told how many of the information tokens they have found and how many are left, thereby implicitly encouraging players to find them all.

The level chosen for implementation in the constrained virtual environment engine was the second level from the full-game version of Discover Babylon, set in the city of Uruk in 3200

BC. It was selected due to its particularly fun and engaging gameplay and story, its environment being well-suited for reproduction as a constrained environment, and its learning content being well balanced between textual information and gameplay interactions. In the level, the player takes on the role of a young scribal student named Taribi. They must leave their house and follow the other scribal students to their school, where they meet their scribal teacher Sasag, who begins the lesson of the day but soon falls sick. He has been poisoned by the game's antagonist, who is wreaking havoc travelling through time, as part of the overarching narrative. The player must make some porridge to heal Sasag, but they do not yet possess the ingredients. They must take some cloth to the market place and trade goods with different characters there to obtain the porridge ingredients. They must then find a bowl, mix the ingredients, and return to Sasag, all before a time limit expires and he perishes. The player learns that a writing tablet may tell them where the antagonist can be found and must find and decode it. This is achieved through a puzzle sequence where real pictographic symbols from that historical period must be matched to their meanings. Afterwards, the player is free to explore the environment before moving on to the next level and the next period and location. This logical flow, as well as all the mechanics and interactions available to the player in the level, are shown in Figure 21.

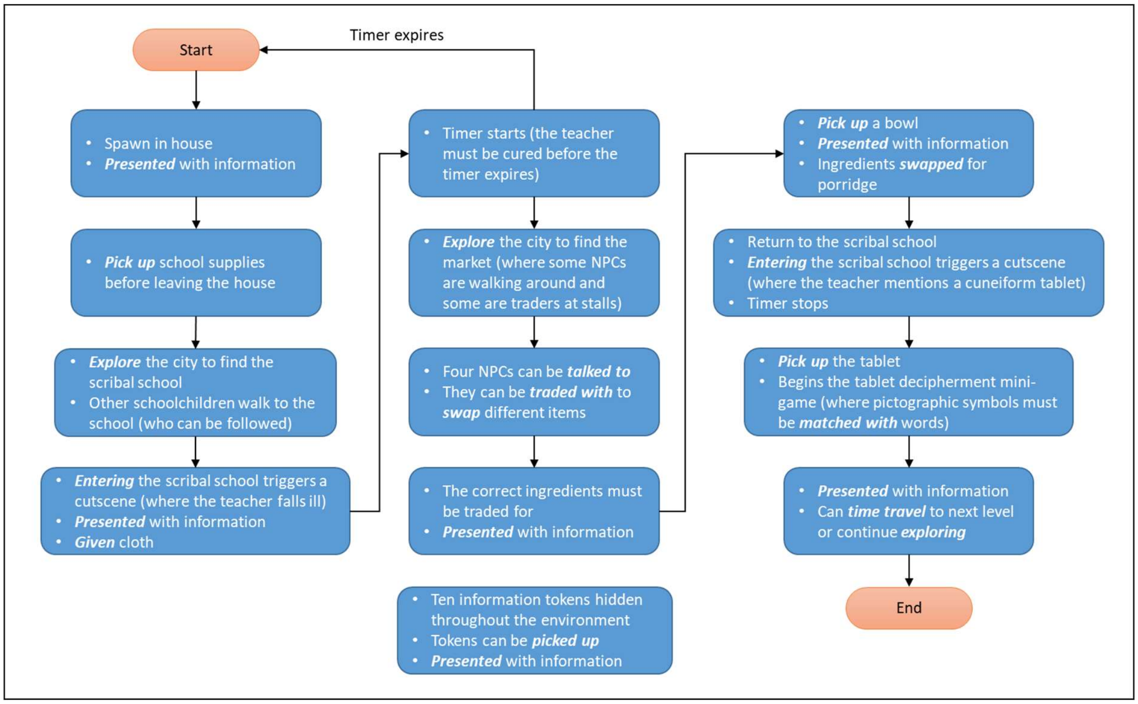


Figure 21. Flow diagram of the game mechanics and logic in the Uruk level of Discover Babylon

The diagram shows the systems and mechanics that the player must interact with, in order, to complete the Uruk level of Discover Babylon (Escape Hatch Entertainment, 2007), and move onto the next. The interactions available to the player are shown in bold.

4.4.2. Implementation of the Environment

The Uruk level was implemented in the constrained environment engine by converting the environment into a set of scenes, each representing a tourist gaze view of an area of the environment. To achieve this, the environment was first charted on paper and the highlights and areas of most interest were identified. Some areas were connected together, representing where players would be able to move between scenes. Each area of interest was converted into a scene by first producing a sketch from screen captures of the 3D environment that gives the player an impression of that area through a single view, as in the application of the tourist gaze theory (Turner, Turner and Carroll, 2005). Those sketches were then converted into a set of layered 2D textures, using typical desktop image manipulation software, which were imported and arranged in the game engine. The visual style utilised in the reproduction of the environment was one of untextured blocks of colour, shaded to represent the lighting conditions for each object, selected due to restrictions on development time and resources, as well as to reduce the comparability of the environment with a photorealistic representation, as detailed by Turner *et al.* (2013). Furthermore, each scene also maximised its use of chiaroscuro lighting, as recommended by Turner & Turner (2006), through simulation of intense sunlight and shadowing. Finally, each scene also maximised the use of parallax and depth-of-field effects by placing many scene objects at different depths. A comparison of different areas of the Uruk environment alongside their reproduction in the constrained virtual environment is shown in Figure 22. The final environment scenes each contained between 2 and 11 layers (median 5), excluding NPCs and the player avatar.

Some experimentation was performed with different post-processing filters, for example the watercolour painting graphical technique described by Bousseau *et al.* (2006) was implemented, shown in Figure 23.d). However, the final version of the constrained environment level did not use any post-processing effects. For further information on different possible non-photorealistic aesthetic techniques, the reader is referred to Kyprianidis *et al.* (2013).

Figure 22. Screen captures of Discover Babylon and the constrained environment implementation

Left column shows screen captures from Discover Babylon of notable areas of the Uruk environment (Escape Hatch Entertainment, 2007), right column shows the corresponding areas reproduced in the constrained environment. These are, from top to bottom, at the foot of the Ziggurat, on the rooves of houses (where an information token is visible on the right side of the screen), inside the scribal school, and talking to a farmer at the market. Reprinted from Hanes and Stone (2019).

4.4.3. Implementation of Navigation

Navigation within the constrained virtual environment was implemented using the scene icon objects described in Section 4.3.2. Each icon is placed in a location in the scene and is shaped as an arrow pointing in a direction of travel that corresponds to the geometry of the scene. Each icon corresponds to one of the links between scenes described in the previous section, and when they are clicked with the mouse or tapped on a touch screen, the current scene will fade out and the new scene will fade in, accompanied by the sound of footsteps. Therefore, travel between scenes is suggested without being exhaustively modelled. These scene transition icons can be seen in Figure 22.b), d), and f). The avatar can also be shown in several different positions in each scene; once the player has arrived in a new scene, their avatar will be shown in a location in the scene corresponding to the direction they came into the scene from, shown in Figure 23.c). The choice of showing the avatar in the scene, effectively using a third-person perspective, was driven by the use of third-person perspective in the base game. The different features of the constrained virtual environment described so far, including the parallax and depth-of-field effects, transition icons, player avatar, and post-processing filters are shown in Figure 23. Furthermore, a short video comparing the environments and navigation mechanisms in the two versions of the game was also produced[22].

[22] The video can be accessed at https://youtu.be/o0K419avYGc

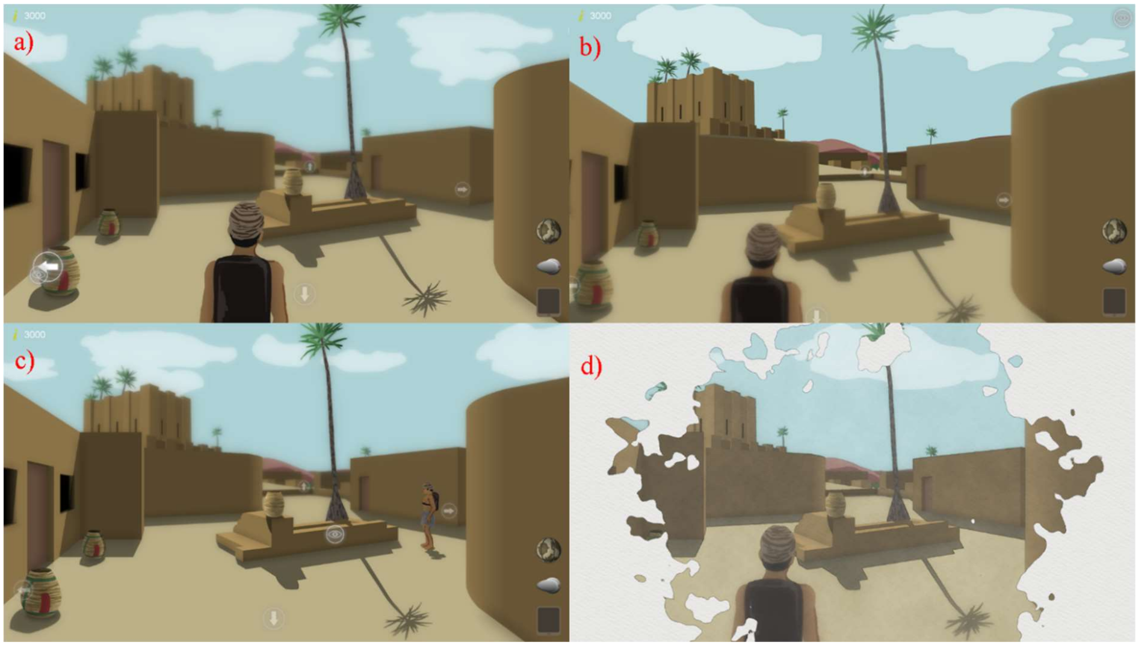


Figure 23. Screen captures from one scene of the constrained environment

a) The cursor moved to a scene transition icon at the bottom-left of the screen, blurring the background; b) the cursor moved to the top-right of the screen, shifting the parallax effect and blurring the foreground; c) moving to the scene from a different direction, thereby changing the position of the player avatar; d) using a watercolour post-processing effect, the scene is rendered as a painting and between-scene transitions are rendered with a paint splashing effect, shown here. Reprinted from Hanes and Stone (2019).

4.4.4. Implementation of Interactions

All the interactions within the Uruk environment of Discover Babylon were implemented using interactive icons in a similar manner to the scene transition icons described in the previous section, where icons are placed at a position and depth within the scene corresponding to what is being interacted with. These icons are also shown with appropriate symbols, for example when the player must interact with their school bags before heading out to the scribal class, a grabbing hand icon is shown over the bag. Similar icons with speech bubble symbols are also used to interact with NPCs, which causes the current scene to change to one of the dialogue scenes. These dialogue scenes utilise a tree-structured dialogue system, where each branch represents a dialogue choice that the player can select. Each branch leads to a different response from the NPC, which can also cause stage directions to run, altering the game state, and leads to a new set of branches for the player to choose from. The information tokens are also implemented as icons using similar graphics to the 3D environment, which can be seen faintly in the right-hand side of Figure 22.d). When the user interacts with one by clicking the mouse or tapping the touch screen, a UI window opens with similar graphics to that in the base Discover Babylon game, showing the information text. Finally, the cursor in the implemented constrained virtual environment, moved across the scene with the mouse or touch screen, was in the shape of an eye as a somewhat literal interpretation of the tourist gaze, to prompt the idea that it represents the point in the scene that the player and their avatar are currently looking at.

4.4.5. Implementation of the Playable Level

The three components of the level described so far; the environment, navigation mechanisms, and interactions, were all combined into a single level to fully reproduce a gameplay experience equivalent to that of the Uruk level of Discover Babylon. Table 6 shows each of the game mechanics, logic, and systems present in the level, how it was implemented in the base game, and how it was recreated in the constrained environment. Due to the rather simple nature of the systems and logic present in Discover Babylon, it was possible to thoroughly observe and document them simply from within the game, without requiring any deeper analysis or access to the game engine or source code. All the game sound effects were also sampled from the base game and reused. The final constrained virtual environment level was fully functional, tested for bugs and errors, and was as closely equivalent to the experience of playing the original level as was possible, with the only differentiating factor being the nature of the environment itself.

The constrained environment implementation of the Uruk level comprised 39 different scenes; 30 navigable environment scenes, 4 dialogue scenes, 2 cutscenes, 1 tablet decipherment puzzle scene, and 2 bookend scenes at the start and end for experiment control. The development process took approximately 170 hours of work, 130 of which were dedicated to the implementation of the environment, and 40 of which were to implement the interactions, game mechanics, and logic to create the playable level. This is significantly lower than what would typically be required to produce a similar 3D environment, although the process was expedited by only needing to implement the environment and mechanics and not design them. It was observed that the skills and specialisms required to design and develop the constrained environment implementation of the level were similar to those typically required to develop a level using an equivalent 3D environment, although the constrained environment (perhaps unsurprisingly) required greater familiarity and proficiency with texture generation and manipulation.

Game Mechanic	3D Environment Implementation	Constrained Environment Implementation
Presenting the player with information	2D UI element appears on the screen showing textual information.	
Picking up objects	A 3D token is shown hovering above the ground in a certain location, moving the avatar into the token triggers the interaction.	An icon is shown in a certain location in a scene, clicking the icon triggers the interaction.
Being given an item	The player has an inventory, shown on the UI, and the item is added to this inventory.	
Exploring the city environment	The avatar is moved in the 3D environment using the keyboard direction controls.	Scenes are viewed by moving the cursor and moving between scenes is performed by clicking movement icons (with arrow symbols) located in each scene.
Entering a specified area	The area is defined on the ground of the environment, and when the avatar is moved into it, the interaction is triggered.	The area is defined as a particular scene, and when the player moves to that scene, the interaction is triggered.
Talking to NPCs	When the avatar is close enough to an NPC, the dialogue can be started by pressing a button, starting a dialogue tree system, where different responses can be chosen by pressing different buttons.	An icon (with a speech symbol) appears above some NPCs, which transitions to a dialogue scene when clicked, starting a dialogue tree system, where different responses can be chosen by clicking different icons.
Trading with NPCs	Trading with NPCs is handled as a selectable branch in the NPC dialogue trees.	
Time travelling to the next level	After completing the level, the player can press a button at any time to interact with a device in their inventory which continues to the next level.	After completing the level, the player can click on a device in the inventory at any time, which continues to the next level.
Cuneiform tablet decipherment mini-game	A separate game mode where a set of symbols must each be matched to the corresponding word. The symbols to be deciphered and possible answers are shown as 2D UI elements.	
Matching symbols with words in the decipherment mini-game	The word is chosen by pressing a corresponding button.	The word is chosen by clicking a corresponding icon.
Timers that start, and actions must be completed before they expire	The timer is shown on the UI, and when it expires some specific logic will be triggered.	
Some NPCs stand idly or walk along predetermined routes	Shown as a 3D animated character stationary or moving through the environment along the route.	Shown as a 2D animated element which is stationary or moves through different positions in different scenes.
Cutscenes are shown at predetermined points	Shown as animated 3D scenes with characters and voices.	Shown as animated 2D scenes with characters and voices.

Table 6. Game mechanics of Discover Babylon and their implementation in the constrained environment

Each of the game mechanics and systems found in the Uruk level of Discover Babylon (Escape Hatch Entertainment, 2007) is shown next to its mode of implementation in the 3D environment of the base game, as well as its recreation in the constrained virtual environment.

4.5. Discussion

4.5.1. Theoretical Limits of Lower-Fidelity Virtual Environments

While the theories of constrained virtual environments are based upon the concepts of make-believe applied to HCI (Turner *et al.*, 2016) and "strong" or "weak" mental representations created by different virtual environments (Turner, Turner and Burrows, 2013), it is relatively unclear where the limits of these theories lie; how far they can be extended and still be successfully implemented. While the shift from 3D environments to parallax-layered 2D environments is certainly a reduction in visual fidelity, it is also doubtless that fidelity could be decreased further. It is therefore interesting to speculate whether a constrained historical environment could be presented through only a static 2D environment, without parallax of depth-of-field effects, or through a combination of static 2D images and text, or indeed through a text-only interface, similar to earlier "text adventure" games. Turner *et al.* (2013) also cite the "book problem" as one of the supporting theories of lower-fidelity environments, though they do not explicitly suggest using only plain text to present the environment. While this may be the furthest that fidelity can be reduced in the digital domain, there are also many possibilities for reduced-fidelity environments in physical table top and board games, which have also been used quite successfully as the target format for serious games and game-based learning in previous research (e.g. Grey *et al.*, 2017; Wasserman and Banks, 2017).

Regardless of the theoretical limits of constrained virtual environments, it is evident that their format, as presented by Turner *et al.* (2013) utilising parallax layers of non-photorealistic 2D images, is a balance between what is visually appealing, what users are accustomed to, the resources required to produce it, and the resulting sense of place and presence, struck out of necessity rather than any particular unique characteristics of the format, per se. Therefore, it may also be informative to observe how the commercial entertainment video game industry treats the concept of high- and low-fidelity environments.

4.5.2. Lessons from the Commercial Video Game Industry

Within the commercial video game industry there are some interesting and noteworthy themes relating to the development and presentation of virtual environments and their respective level of fidelity. The first is a trend of purposeful reduction of fidelity in commercial game environments, particularly within the independent games sector, where budgets, manpower, and resources are typically much lower (Hall, 2008). These games commonly utilise 2D assets as well as innovative non-photorealistic rendering and visual styles to create games and environments that are visually appealing and can create a convincing sense of place. For example, Machinarium (Amanita Design, 2009) uses a hand-drawn 2D art style to create a charming and vivid sense of place in a "point-and-click adventure game", shown in Figure 24. Another style of game utilising simplified 2D assets, environments, and character animations is "Bishoujo" games, a form of Japanese dating simulation game, based upon the aesthetic style of manga and anime cartoons. Jones (2005) describes the ways in which Bishoujo games can enhance the user's sense of presence and also transmit cultural information through strategic use of these simple assets. Finally, another common technique in the independent games sector is to draw upon older graphical technology and design techniques in what are dubbed "retro" games, including low resolution pixel art and sounds, reminiscent of the technical limitations of earlier gaming hardware, as well as text console-based "text adventure" games. For example, Sonic Mania (PagodaWest Games and Headcannon, 2017) uses pixel art and low-quality sound effects to create a nostalgia-driven remake of Sonic games from years ago, shown in Figure 25.

The game was highly critically acclaimed upon release, receiving an average score of 86% from 70 critic reviews on the critic aggregator website Metacritic (2017). Therefore, overall it can be said that within the commercial entertainment video game industry, there is scope and desire among players for lower-fidelity games and environments.

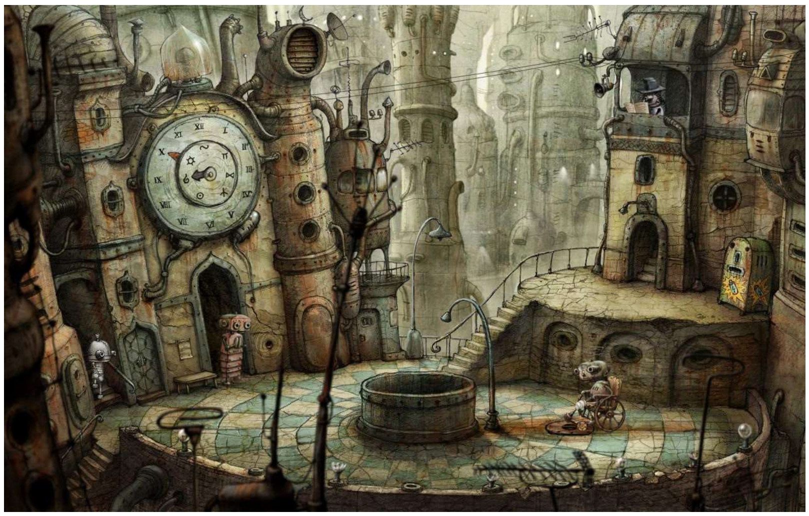


Figure 24. Screen capture from "Machinarium"

Machinarium (Amanita Design, 2009) is a "point-and-click adventure game" that creates vivid environments with a strong sense of place through layered 2D assets utilising a hand-drawn aesthetic style. © Amanita Design.

Figure 25. Screen capture from "Sonic Mania"

Sonic Mania (PagodaWest Games and Headcannon, 2017) is a 2D platformer game that uses intentionally low-fidelity assets to create a "retro" audio-visual style reminiscent of older games in the Sonic series that were restricted by hardware limitations of the time. © SEGA.

However, there is simultaneously a great drive towards increased fidelity within the same industry. This is true both for new "triple-A" games that utilise and push the boundaries of the state-of-the-art in graphics technology, as well as increased-fidelity "high-definition" remakes of older games. Therefore, it can also be stated that modern players of entertainment games desire to play games with the most advanced graphical technology the state-of-the-art can offer, and they also desire to see their favourite games from the past remade using these new standards.

In conclusion, there is overall a push in both directions, towards reduced-fidelity and increased-fidelity games and environments within the commercial game industry. Therefore, the lesson to take away is that lower fidelity games can be accepted and even cherished by modern game players, however the correct approach must be taken carefully. By observing independent and retro games, it becomes clear that the lower-fidelity approach must be fully integrated into and embraced by the design process to be successful, and not simply used out of necessity.

4.5.3. Opportunities for Applying Constrained Virtual Environments to Serious Games for Heritage

Constrained virtual environments offer several benefits and opportunities for the development and implementation of serious games for heritage. Firstly, they avoid the pitfall highlighted by Michael and Chen (2006) that serious games must always utilise the latest and most advanced games technology, thereby greatly reducing the required resources and budget to design, capture, develop, and test the constrained environments (Turner, Turner and Burrows, 2013). Furthermore, by reducing the focus of the historical environment on visual presentation, there could be potential for greater exploration of meaning interpretation of the historical content

(Tan and Rahaman, 2009), as well as phenomenological and hermeneutic interpretation of the environments (Champion, 2008b; Falconer and Scott, 2018).

There is also a potential for non-photorealistic rendering, which constrained virtual environments utilise and embrace, for historical content. Roussou (2008) supports non-photorealistic rendering in heritage and likens it to post-impressionism in painting, where the immediate resemblance to the subject is reduced, but the higher-level meanings and expressions are maintained, and even amplified, by the medium. Furthermore, non-photorealistic rendering also offers the possibility for creating SGsH with greater visual appeal for players, while keeping the required development resources low. Finally, non-photorealistic rendering and the inherent nature of constrained virtual environments to present information without showing it in exhaustive graphical detail offer interesting solutions to some of the issues outlined for serious games for heritage. For example, the issues of violence, inappropriate content, and historical uncertainty within the subject matter (Champion, 2016, 2017a) might all be addressed through strategically selecting which aspects of the content are shown in detail and which are merely suggested.

4.5.4. Challenges for Applying Constrained Virtual Environments to Serious Games for Heritage

Nevertheless, there are also many challenges of successfully applying constrained virtual environments to serious games for heritage. Chief among these is likely the concern over the effect of non-photorealistic rendering and intentionally reduced fidelity on accuracy and authenticity within the historical content and source material, especially as it has been shown that players often assume that more photorealistic representations are more accurate (Roussou, 2008). However, while these factors must continue to be a primary focus of SGH designers when utilising constrained environments, there are also past researchers who have criticised them. Copplestone (2017) has highlighted how the concepts of accuracy and authenticity are interpreted and assessed in very different ways by different audiences, such as players, critics, and heritage experts. It was argued by Westera *et al.* (2008) that in serious games, high-fidelity representations are not required to provoke responses from players, but representations with believability and internal consistency; "what counts is not realism or authenticity but credibility". Finally, Roussou (2008) also criticised the concept of authenticity being used in virtual heritage environments, arguing it represents a paradox because we cannot ever know the benchmark against which to evaluate content as being authentic or not.

Next, the way in which constrained virtual environments present spatial information, and how this is parsed and internalised by the player, is unknown. Past research has focused on how such information is interpreted by players in 3D virtual heritage environments (Debailleux, Hismans and Duroisin, 2018), and establishing the efficacy of constrained environments at transmitting such spatial information should be a priority of future work. Finally, experimental validation is now greatly needed to ascertain the effectiveness of serious games for heritage utilising constrained virtual environments at creating a sense of historical place and presence for the player, as well as being engaging and appealing, while also achieving their learning objectives. However, an initial attempt at such evaluation will be performed in Chapter 5.

4.5.5. Manifesting Historical Content through Constrained Virtual Environments

Constrained virtual environments will both necessitate and afford some differences in the manifestation of historical content when compared with traditional 3D environments. Relating to the model of historical content presented in Chapter 3, the capability of the learning outcome should be totally unchanged in a constrained environment, as should the taxonomical category of the instructional content. However, as mentioned in the previous section, due to the variable level of detail possible in constrained environments, they should offer more freedom to define and adjust the focus with which the historical content is presented. In the characteristics of the manifestation itself, the means of manifestation will often be different by necessity, since most content would need to be manifested in 2D rather than 3D form. However, there is also opportunity for presenting images of individual artefacts, overlaid on top of the constrained environment, even 3D models which could be viewed, rotated, and inspected by the player. Otherwise, verbal and aural manifestations should remain unchanged, with some minor differences in mechanical manifestations, due to differences in the mechanisms used to navigate the environment. Constrained virtual environments should also offer more possibilities for the level of demonstration of historical manifestations, due to the possibility of presenting content in more abstracted forms. Finally, the tone of manifestations should be the same as that seen in 3D environments.

It is proposed that Assyriology and ancient Mesopotamian history, as a field, is particularly well-suited to the use of constrained virtual environments for three reasons. Firstly, because there are many aspects of an ancient Mesopotamian virtual environment where the level of historical knowledge and confidence is lower, due to a lack of archaeological evidence and examples of surviving artefacts, which can therefore be shown with proportionately lower graphical detail. However, aspects of the environments, such as specific architecture or artefacts, where there is a greater level of historical knowledge, could be presented with a proportionately higher level of graphical detail. Secondly, because the field of Assyriology contains a wealth of small artefacts that have survived, especially cuneiform tablets, which could be easily rendered and viewed as either high-quality 2D photographs or even 3D models, overlaid on top of the constrained virtual environment. Finally, the field also features some large-scale and visually distinct architecture, such as ziggurats, temples, and palaces, which can be effectively presented, giving the player a strong impression of their characteristics, through a small number of selected views. This makes constrained virtual environments particularly suitable for presenting environments depicting buildings and cities from different periods and locations within ancient Mesopotamia.

4.5.6. Achieving Meaningful Integration of Play and Learning through Constrained Virtual Environments

It is expected that the constrained virtual environment format will neither positively nor negatively affect the capacity for serious games for heritage to achieve meaningful integration of play and learning. This is due to the fact that meaningful integration of play and learning in a serious game is mostly dependent upon the game mechanics and their context, in terms of aesthetics and meanings, and the fact that SGsH utilising constrained virtual environments are not expected to be fundamentally different from those utilising traditional 3D environments in terms of their mechanics.

4.6. Conclusions

4.6.1. Chapter Conclusions

This chapter addressed the second secondary research question of the project. In doing so, the approach taken to the development of serious games for heritage utilising constrained virtual environments was justified, in which focus is applied to recreating existing serious games for heritage with constrained environments. The development of a game engine utilising constrained virtual environments was described, as was the full implementation of the second level of the SGH Discover Babylon in the game engine, set in the ancient Mesopotamian city of Uruk in 3200 BC. The implementation of the constrained environment required significantly less resources, and similar skills and proficiencies, to the development of an equivalent 3D environment.

Finally, several different aspects of constrained virtual environments in SGsH were discussed, including the theoretical limits of constrained environments, lessons to be taken away from the commercial video game industry, opportunities and challenges for utilising constrained environments in serious games for heritage, the implications for the manifestation of historical content, and the implications for the meaningful integration of play and learning. The theory and applications of constrained virtual environments for serious games for heritage have now been well documented and discussed, and an implementation of one level from Discover Babylon utilising a constrained environment is now completed and ready to be compared experimentally against the original version of the serious game.

4.6.2. Applications to the Thesis

As was conceded by Turner *et al.* (2013), the authors had not performed any direct comparisons between a constrained virtual environment and an equivalent 3D environment. A similar evaluation was suggested by Hainey *et al.* (2016), who stated that there was a lack of comparisons of 2D and 3D environments for serious games, to ascertain whether "immersive 3D" environments are indeed necessary to achieve the same objectives. Therefore, in Chapter 5 the implemented level from Discover Babylon utilising a constrained virtual environment will be evaluated experimentally in a direct comparison with the original level utilising a 3D environment.

Chapter 5 Evaluating Constrained Virtual Environments for Serious Games for Heritage

5.1. Introduction

5.1.1. Chapter Introduction

This chapter will address the third secondary research question by evaluating the application of constrained virtual environments to serious games for heritage through an experimental investigation. The experiment will test the constrained environment implementation of the Uruk level of Discover Babylon, described in Chapter 4, against the original version to ascertain the extent to which the constrained environment can still achieve the aims of the base serious game. These aims relate to the sense of presence and place within the historical environment that players experience while playing, the extent of learning that takes place during the serious game, the level of interest in the subject matter amongst players afterwards, and finally, creating a quality experience of fun and engaging gameplay. Furthermore, the feasibility of implementing serious games for heritage based on constrained environments in physical museum displays will be investigated through collaboration with a museum expert who was invited to play the game and give their opinions on the issue.

The chapter will first lay out the aims, rationale, and methodology of the experiment, including what it hopes to measure and how it intends to measure it, and the pilot test that was performed and the recruitment of experimental participants. Then, the results and subsequent analysis will be enumerated. Finally, each of the results will be discussed, culminating in an initial set of guidelines being created, to guide and advise the design and development of serious games for heritage implementing constrained virtual environments in the future. An overall evaluation of the efficacy of such serious games utilising constrained environments will finally also be given, as well as a description of future research in this area.

5.1.2. Statement of Published Work

Much of the work detailed in this chapter, including the experimental results and subsequent discussion was published in a journal paper (Hanes and Stone, 2019) with the current author as first author and the supervisor as co-author. Accordingly, there are some instances of reused images or text between this chapter and the publication. It should be emphasised that the current author was responsible for the development of the work detailed in this publication, as well as writing the manuscript, with the supervisor taking an advisory role.

5.2. Methodology

5.2.1. Experimental Objectives

The main objective of the experiment is to investigate the extent to which serious games for heritage utilising constrained virtual environments are equivalent to those implemented with 3D environments at achieving their stated aims. This approach was recommended by Hainey *et al.* (2016) to determine whether the development of elaborate 3D serious games, which is expensive and resource-intensive, is actually necessary, or whether 2D serious games can suffice.

It is worth briefly addressing the fact that the experiment does not aim to investigate whether serious games for heritage utilising either constrained or 3D environments are equivalent to traditional instructional material. While this would undoubtably be a valuable line of investigation, a comparison of constrained and 3D environments is considered the more important aim of this investigation. Furthermore, an approach including the evaluation of traditional forms of learning would also add considerable extra workload to the experiment and subsequent analysis, when it would be better evaluated in other experiments.

The main experimental objective can be broken down into five sub-objectives, each with an associated hypothesis-pair that will be tested through the experiment, shown in Table 7. These sub-objectives are as follows:

Sub-objective A is to compare participants' experience of the historical environment and their sense of "engagement" or "immersion" in being able to move an avatar within and interact with the environment. As was described in Section 2.6 in the literature review, it was determined that the most effective and reliable means of measuring these complex experiential concepts is through presence.

Sub-objective B is to compare the extent to which participants enjoy the serious games and feel that they are a quality experience. This approach is supported by Giannakos (2013), who found enjoyment to be an important factor in serious games that can affect learning. Measuring this is most feasibly achieved through subjective self-assessment.

Sub-objective C is to compare the extent to which players are motivated to explore the historical environment. As was described in Section 4.4.1, the base SGH Discover Babylon contained ten information tokens spread throughout the environment. The number of information tokens participants willingly collect before deciding to end the level represents an objective, quantitative measure of the extent to which participants are motivated to explore the environment.

Sub-objective D is to compare participants' extent of learning, specifically cognitive knowledge gain, through playing the SGH. While more abstract, constructivist notions of learning and meaning-making are also very important for SGsH, as was discussed in Section 1.3.2, knowledge gain represents a more objective metric that can be measured more reliably in the current experiment.

Finally, sub-objective E is to compare the extent to which players are interested in the subject material after playing the serious game and wish to learn more. While this can be measured through subjective self-assessment, an objective measure of interest can also be taken through asking participants whether they perform any voluntary pursuit of further information on the subject matter after the experiment is completed.

There are also two additional aims of the experiment. The first of these is to investigate correlations and relationships between the five areas of investigation already described. The second is to investigate and highlight areas for further research, including especially challenging aspects of applying constrained virtual environments to serious games for heritage and areas of opportunity.

Experiment Sub-Objective	Hypothesis Version	Hypothesis Code	Hypothesis
A	0	$H_{A,0}$	The level of presence experienced by participants while playing the serious game for heritage utilising a 3D environment is the same as participants while playing the SGH utilising a constrained virtual environment.
	1	$H_{A,1}$	The level of presence experienced by participants while playing the serious game for heritage utilising a 3D environment is different from participants while playing the SGH utilising a constrained virtual environment.
B	0	$H_{B,0}$	Enjoyment and perception of quality amongst participants while playing the serious game for heritage utilising a 3D environment is the same as participants after playing the SGH utilising a constrained virtual environment.
	1	$H_{B,1}$	Enjoyment and perception of quality amongst participants while playing the serious game for heritage utilising a 3D environment is different from participants after playing the SGH utilising a constrained virtual environment.
C	0	$H_{C,0}$	The number of information tokens collected by participants while playing the serious game for heritage utilising a 3D environment is the same as participants while playing the SGH utilising a constrained virtual environment.
	1	$H_{C,1}$	The number of information tokens collected by participants while playing the serious game for heritage utilising a 3D environment is different from participants while playing the SGH utilising a constrained virtual environment.
D	0	$H_{D,0}$	Knowledge gain amongst participants playing the serious game for heritage utilising a 3D environment is the same as participants playing the SGH utilising a constrained virtual environment.
	1	$H_{D,1}$	Knowledge gain amongst participants playing the serious game for heritage utilising a 3D environment is different from participants playing the SGH utilising a constrained virtual environment.
E	0	$H_{E,0}$	Interest in the subject matter and voluntary pursuit of more information amongst participants after playing the serious game for heritage utilising a 3D environment is the same as participants after playing the SGH utilising a constrained virtual environment.
	1	$H_{E,1}$	Interest in the subject matter and voluntary pursuit of more information amongst participants after playing the serious game for heritage utilising a 3D environment is different from participants after playing the SGH utilising a constrained virtual environment.

Table 7. Experimental hypotheses for evaluating constrained environments in serious games for heritage

The null and alternate hypotheses for each of the five sub-objectives of the experiment comparing the serious game for heritage Discover Babylon (Escape Hatch Entertainment, 2007) implemented with 3D and constrained virtual environments.

5.2.2. Experimental Methodology

a) Experimental Design

The experimental procedure was a two-group independent samples design, where one group plays the Uruk level in the base serious game Discover Babylon, hereafter referred to as the "3D Environment group", and the other group plays the constrained environment implementation of the same level, hereafter referred to as the "Constrained Environment group". Another possible experimental procedure is the repeated samples design, where every participant plays both versions of the game. This, however, would not be ideal because this design precludes the collection of any longitudinal data, and because participants could not be realistically expected to play what is effectively the same game twice and react the same way to it the second time. Participants were randomly assigned to one of the two groups, an approach recommended by Hainey *et al.* (2016). This is also because a matched-pair design, where participant pairs are matched based on some pre-game metric and one is assigned to each experimental group, was not possible with the given logistical constraints of the experiment. The controlled variable between the two groups was the environment type, being either 3D or constrained, whereas all other variables were kept as constant as possible. However, one exception to this was the mode of interaction the player has with the game. Discover Babylon can only be interacted with through the keyboard, as most people find this the most natural control setup for navigating an avatar through a 3D environment. The constrained environment, however, is interacted with using a mouse, as this is the most fitting control scheme for moving a cursor across the screen. It may have been possible to keep the mode of interaction constant or even treat it as a second independent variable, however it was decided that the two environment types should be compared while utilising the most fitting control scheme that would be used with such games in the real world.

b) Experimental Measurements

Although some experimental measurements were taken directly from the participants' gameplay, it was decided that most of the measurements should be made through questionnaires. This is the most typical approach taken by other researchers, and was also recommended by Champion *et al.* (2012), who attempted to evaluate interactions in an SGH through game-based performance measures, but concluded that the complexity and context-sensitivity of such interactions made questionnaires a more reliable method. It was also decided, according to the recommendation of several past researchers (Backlund and Hendrix, 2013; Hainey *et al.*, 2016), that the experiment should attempt to measure longitudinal effects of the serious game for heritage as an intervention for increasing knowledge and interest in the subject matter. Therefore, the experiment made additional measurements three months after the serious game was played.

For the first experimental sub-objective, presence was measured using the Slater-Usoh-Steed post-experience presence questionnaire (Slater, Usoh and Steed, 1994), chosen due to its extensive use by other presence researchers, its ease to be adapted to any virtual environment, and its short length, comprising only six seven-point Likert scale questions.

For the second sub-objective, knowledge gain was measured through repeated applications of a test on Mesopotamian history knowledge, to be administered both pre-game and post-game, an approach used by other serious game researchers (Froschauer *et al.*, 2010; Catalano, Luccini and Mortara, 2014). The test was also administered at the three-month post-game stage. The test was designed in conjunction with the field expert introduced in Section 1.6, and contained 24 questions. 10 questions were based on the information tokens found in the environment, where each information token provided the information to be able to correctly answer one of the questions. 9 questions were based on the information participants are exposed to through completing the objectives and story of the Uruk level. The final five questions were unrelated to the information provided in the game, and were added to reduce the priming effects of using pre-game questions, as recommended by Mortara *et al.* (2013). As per their recommendations, the order of the questions was also different at each stage of the experiment. The questions were designed such that they were unambiguous to mark, using either true/false or one-word answers.

For the third sub-objective, the information tokens collected while participants played was measured through silent observations. For the fourth sub-objective, voluntary pursuit of further information was measured by asking participants, three months after completing the experiment, whether they had or planned to take further steps to learn more about Mesopotamian history.

Finally, for the fifth sub-objective, self-evaluated enjoyment of the game was measured using a five-point Likert scale. The quality of the game was measured by asking participants to give the game ratings out of 10 in eight different categories; navigation, sound, text, interactions, aesthetics, locations, characters, and engagement, similar to the rating system used by Turner *et al.* (2013).

c) Experimental Procedure

Participants were first presented with an information and consent form, giving them details of what the experiment involved, what would be recorded, and reassuring them of the ethical usage of their data (shown in Appendix I.1). After signing this form, participants were presented with a pre-game questionnaire, to collect demographic information, their educational discipline, their familiarity with Mesopotamian history, how frequently they played video games, and containing the pre-game test of knowledge on Mesopotamian history (shown in Appendix I.2). Participants were then given an information sheet to introduce the game narrative and instruct them how to interact with the version of the game they would be playing (shown in Appendix I.3). Participants were instructed to take the game at their own pace and play for as long as they wished.

Participants then played one of the two versions of the game, depending on the experimental group they were randomly assigned to. Participants sat in a quiet testing laboratory in the Gisbert Kapp building at the University of Birmingham, at a desktop PC with a large ultra-high definition ("4K") monitor and in-ear headphones. Participants in the 3D Environment group controlled the game avatar with a keyboard, using the arrow keys for movement and numpad keys for interactions. Participants in the Constrained Environment group used a trackball mouse to move the cursor and the mouse button for interactions. The experimental setup is shown in Figure 26 for a participant from the 3D Environment group.

Figure 26. Experimental hardware setup for participants in the Discover Babylon environment experiment

A participant plays the 3D environment version of the Uruk level in Discover Babylon, at a desktop PC situated in a quiet laboratory, using a keyboard and in-ear headphones. Reprinted from Hanes and Stone (2019).

As each participant played the level, a coordinator silently observed them, documenting which of the information tokens they collected, as well as their real-life and in-game behaviours, the speed with which they learned how to interact with the game, as well as the proficiency with which they could complete the game challenges.

Afterwards, participants completed a post-game questionnaire (shown in Appendix I.4), assessing their enjoyment of the game and the degree to which it increased their interest in the subject matter, both measured with 5-point Likert scales, and the ratings out of 10 across each of the eight categories. The questionnaire also included the Slater-Usoh-Steed presence questionnaire (Slater, Usoh and Steed, 1994) and the post-game stage of the test on Mesopotamian history. Participants then completed a short semi-structured interview (shown in Appendix I.5), asking them to recount their experiences within the virtual environment, their personal styles of navigation, their motivation to collect the information tokens, and their most and least favoured aspects of the game. Shortly after the experiment, they were sent an email (shown in Appendix I.6) providing several online links where they could learn more about the subject matter, in case the game had roused their interest.

Three months after completing the experiment, participants were asked to complete another questionnaire online (shown in Appendix I.7). This long-term questionnaire asked participants to re-rate the degree to which the SGH had increased their interest in the subject matter, again on a 5-point Likert scale, and asked them if they had performed, or planned to perform, any further steps to learn more about Mesopotamian history. Finally, the long-term questionnaire also contained a third stage of the test, to test their retention of any knowledge gained.

Finally, after all experimental data was collected, two prizes were randomly assigned and awarded to two participants. These were a £100 and a £50 Amazon voucher.

5.2.3. Experiment Pilot Test

A pilot test was performed, based on the experimental methodology described above, to trial the procedures and identify any weaknesses of the experimental design, and to inform the design of the constrained virtual environment. Five postgraduate students from the University of Birmingham took part in the pilot test, three playing the 3D version of the game, and two playing the constrained environment version of the game. The resulting feedback prompted the addition of the feature whereby the position of the player's avatar in each scene changed based on the scene they had transitioned from, described in Section 4.4.3. It was decided that the experimental procedures were effective and were fit be carried out on the main cohort of participants. Out of the three participants who played the 3D environment version of the game, two completed the level, whereas one asked to stop and said they were no longer interested in performing the experiment. Therefore, the data from the two participants who completed the 3D version of the level could be included in the main cohort.

5.2.4. Experimental Participants

A further 32 participants were recruited for the main stage of the experiment, resulting in a cohort of 34 (with the two from the pilot test). These participants were recruited through posters placed on noticeboards around the university campus and flyers handed out during a departmental lecture, who registered their interest through a signup website. Therefore, 17 participants were randomly assigned to each experimental group, and every participant completed the entire story aspect of the level, explored the environment to whatever extent they wanted, and completed the pre-game, post-game, and long-term questionnaires. Due to ethical and logistical constraints, the participants were all aged over 18, which is older than the stated target audience of Discover Babylon, an issue that is discussed further in Section 5.4.11, with other limitations of the experiment. Experimental testing took place between October 2017 and April 2018. Finally, an expert in the field of digital technology in museum displays from Arts Council England was also invited to come and play the constrained environment version of the game and be interviewed to discuss their reaction to the game and the feasibility of implementing such games within physical museum displays. The corresponding interview questions are shown in Table 8.

Can you briefly describe the experience you just had?
Can you briefly describe the places you visited while playing?
How did you find it exploring and navigating those places?
While you were playing, how immersed in the world did you feel? Why?
Did you feel that you wanted to collect all of the information tokens?
What were your favourite aspects of the game you played?
What were your least favourite aspects?
What is your educational and professional background?
What is your reaction to this game's use of constrained virtual environments?
How would you feel about implementing such a game in a museum display?
What do you think would be the different challenges of implementing such a game in a museum display?
Are there any examples of museums that successfully implement similar games?
Would there be interest in implementing such games in museums or cultural institutions?

Table 8. Questions asked in the museum expert interview.

5.3. Results

5.3.1. Participant Characteristics

In the 3D Environment group, participant ages ranged from 18 to 29 with a mean of 22.6 years and standard deviation of 3.9 years. In the Constrained Environment group, participant ages ranged from 18 to 41 with a mean of 23.8 years and standard deviation of 6.4 years. The participant genders, educational disciplines, initial familiarity with Mesopotamian history, and frequency of playing video games are shown in Figure 27 for the two experimental groups.

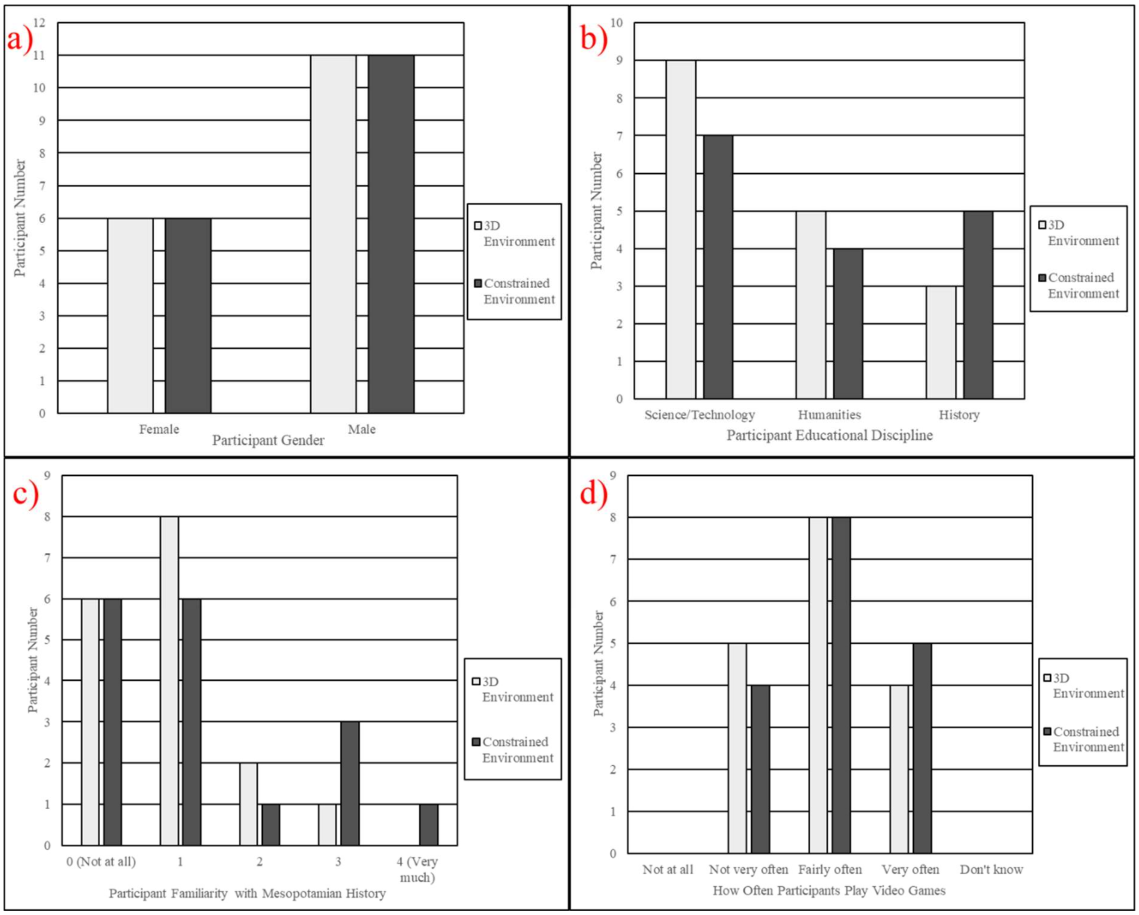


Figure 27. Constrained environment experimental participant characteristics

a) Distributions of participant genders between experimental groups; b) distributions of participant educational disciplines between experimental groups; c) distributions of participant familiarity with Mesopotamian history between experimental groups; d) distributions of participant frequency of playing video games between experimental groups. Reprinted from Hanes and Stone (2019).

5.3.2. Comparison of Presence

For each experimental group, the Cronbach Alpha was calculated for the six questions of the Slater-Usoh-Steed presence questionnaire. The resulting ratings were 0.81 (“good” rating) for the 3D Environment group and 0.88 (“good” rating) for the Constrained Environment group. Therefore, mean presence ratings were calculated for each participant by coding the 7-point

Likert scale from 0 to 6 and calculating the mean of the six answers, the distributions of which are shown in Figure 28.

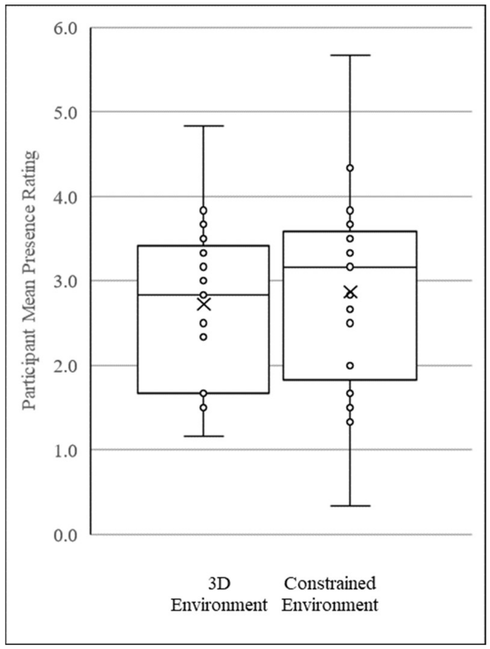


Figure 28. Mean presence ratings between the two experimental groups

Box-and-whisker plots of mean presence ratings for the 3D Environment and Constrained Environment experimental groups. Reprinted from Hanes and Stone (2019).

A comparison of mean presence ratings between the two experimental groups was performed. The Shapiro-Wilk normality test found that neither the 3D Environment group, $W(17) = 0.96$, $p > 0.05$, nor the Constrained Environment group, $W(17) = 0.98$, $p > 0.05$, had a significantly non-normal distribution. Levene's test of the untransformed means found the variances for the two test conditions to be equal, $F(1, 32) = 0.56$, $p > 0.05$. Therefore, an independent t-test was performed, and the difference was not significant, $t(32) = 0.38$, $p > 0.05$, with a negligible effect size, $r = 0.07$. The 95% confidence interval corresponded to an inter-group difference of -0.94 to +0.65.

During the interviews, when asked to recount their experience of the Uruk environment and whether they felt present or immersed there, participants gave a range of responses. Several participants said they felt immersed because of the “task” or because of the “story and the goals”, whereas one participant, CP01, noted the opposite effect; “The task overrode the feeling of being somewhere”. Most participants described the characteristics of the game and how they led to or did not lead to a sense of presence or immersion, whereas only one participant, TP15, mentioned the hardware and experimental setup, stating that the large screen and absence of distractions helped them to achieve a sense of immersion. Finally, one participant in the Constrained Environment group, TP01, spoke very positively of their feelings of presence and sense of place in the environment: "I felt like I am really in the city… although the graphic is not great compared to modern games, but it was really good, the feeling of the river, the feeling of the ziggurat… The experience, like I have been in the city. Yeah, I am walking in Uruk, it's real [laughs]". This participant said they were from Iraq and so felt a greater emotional connection with the environment.

5.3.3. Comparison of Perceived Game Quality

The scores the participants assigned to the games are shown in Table 9, with means and standard deviations, across each category for the two experimental groups, as well as the mean of all eight categories, hereafter referred to as the “mean game score”. The distributions of the mean game score for the two experimental groups are shown in Figure 29.

Score Category	3D Environment Group		Constrained Environment Group	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Navigation	5.94	2.01	5.47	1.94
Sound	6.65	2.00	5.94	2.22
Text	7.29	1.83	7.65	1.62
Interactions	7.12	1.27	6.82	1.78
Aesthetics	5.94	1.56	5.71	1.96
Locations	6.24	1.86	6.24	1.75
Characters	6.41	1.62	5.12	1.73
Engagement	7.35	1.69	6.94	1.89
Mean	**6.43**	**1.33**	**6.09**	**1.40**

Table 9. 3D environment and constrained environment participant game scores

Scores out of 10 assigned to the games across eight categories by participants from the two experimental groups. Reprinted from Hanes and Stone (2019).

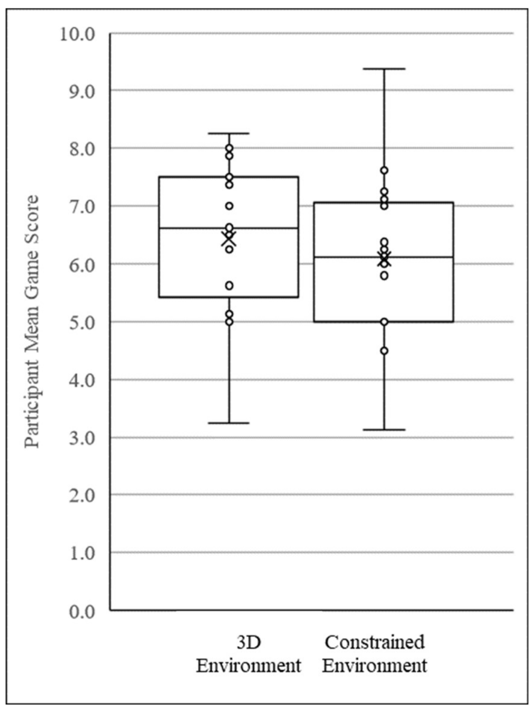


Figure 29. Mean game scores between the two experimental groups

Box-and-whisker plots of the mean game scores for the 3D Environment and Constrained Environment experimental groups. Reprinted from Hanes and Stone (2019).

A comparison of mean game score for the two experimental groups was performed. The Shapiro-Wilk normality test found that neither the 3D Environment group, $D(17) = 0.13$, $p > 0.05$, nor the Constrained Environment group, $D(17) = 0.11$, $p > 0.05$, were significantly non-normal. Levene's test of the untransformed means found the variances for the two test conditions to be equal, $F(1, 32) = 0.00$, $p > 0.05$. Therefore, an independent t-test was performed, and the difference was not significant, $t(32) = 0.81$, $p > 0.05$, the effect size was found to be small, $r = 0.14$. The 95% confidence interval corresponded to an inter-group difference of -0.59 to +1.37.

There were some significant correlations between the ratings of enjoyment, mean game score, and mean presence, shown in Table 10.

Variable 1	Variable 2	Test	Test Value	Significance
Mean game score	Mean presence	Pearson's R	$r = 0.53$	**$p = 0.001$**
Enjoyment	Mean presence	Spearman's Rho	$r_s = 0.35$	**$p < 0.05$**
Enjoyment	Mean game score	Spearman's Rho	$r_s = 0.71$	**$p < 0.001$**

Table 10. Constrained and 3D environment significant participant correlations

Significant correlations between participant results for presence, game score, and enjoyment, calculated for all participants together from both experimental groups.

Finally, during the interviews, participants gave mixed responses when talking about the game they played. Within the Constrained Environment group, participant TP06 wanted the graphics to be more "dynamic" and "3D" and participant TP08 said they were more used to 3D environments. However, TP17 stated that they found the game to be 3D instead of 2D, and TP05 spoke positively of the game's parallax effect: "I did kinda like as well that [the layers of the environment] moved with [the mouse cursor], it was a 2D drawing but it felt 3D at the same time, which made it more immersive I think".

5.3.4. Comparison of Information Token Collection

During the game, participants in the 3D Environment group collected a mean of 6.29 information tokens, standard deviation 2.52, whereas participants in the Constrained

Environment group collected a mean of 8.06 information tokens, standard deviation 2.08. The distributions of information token numbers for both experimental groups are shown in Figure 30. A non-parametric comparison, using a Mann-Whitney U test, was performed and the number of information tokens collected in the 3D Environment did differ significantly from the Constrained Environment, $U = 81.50$, $z = -2.21$, $p < 0.05$, and the effect size was medium, $r = -0.38$. When asked about the information tokens during the interviews, most of the participants described wanting to collect all of them (82% 3D Environment, 88% Constrained Environment, 85% overall), some even describing themselves as “completionists” or “collect-a-maniacs”. Some of the participants highlighted some specific aspect of the game that made them less want to collect the information tokens (41% 3D Environment, 18% Constrained Environment, 29% overall), of which the most common reasons were slow movement or difficult navigation. It was also observed that some participants were not very interested in reading the information contained in the information tokens; they were motivated to collect all the tokens, but upon finding each they would close the information panel that appears without reading it.

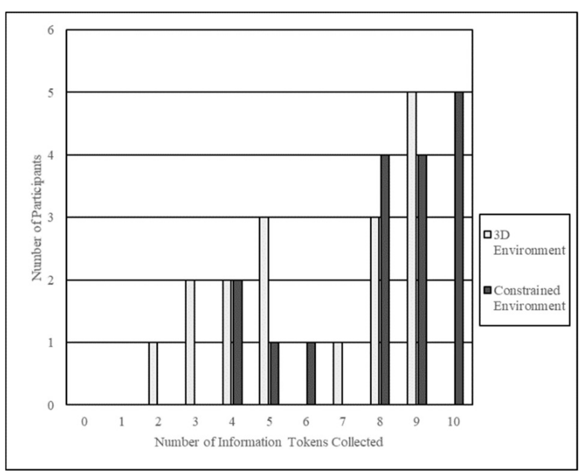


Figure 30. Number of information tokens collected between experimental groups

The distributions of the numbers of information tokens collected while playing the game, shown for the 3D Environment and Constrained Environment experimental groups. Reprinted from Hanes and Stone (2019).

When the number of information tokens collected was compared against mean game score for both experimental groups, it revealed a distinct split in the cohort, shown in Figure 31. When considering all participants who collected seven or fewer tokens, the number of information tokens collected was significantly correlated with mean game score according to a Pearson's R test, $r = 0.67$, $p < 0.05$.

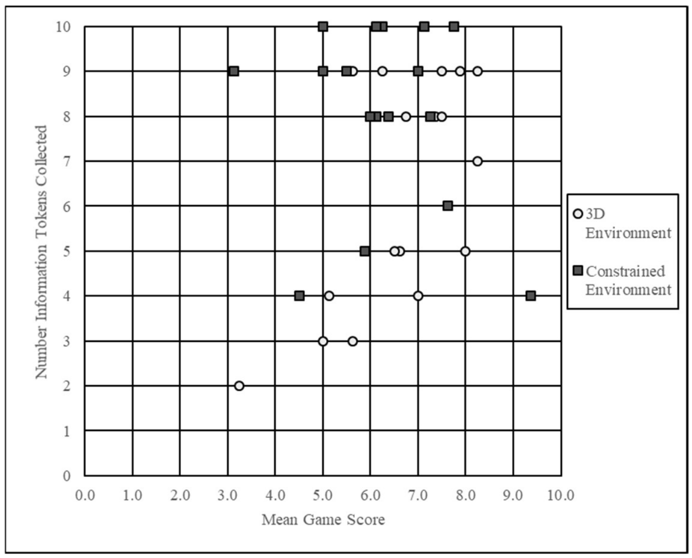


Figure 31. Mean game score against information token number for the two experimental groups

Participant mean game score plotted against the number of information tokens collected within the game environment, for the 3D Environment and Constrained Environment experimental groups.

5.3.5. Comparison of Learning

The participant pre-game, post-game, and long-term mean test scores are shown, for the nine questions based on the story of the level and the ten questions based on the information tokens, in Table 11.

		3D Environment group		Constrained Environment group	
		Mean	Standard Deviation	Mean	Standard Deviation
Story questions (/9)	*Pre-Game*	1.53	1.81	3.24	2.86
	Post-Game	5.41	1.70	5.71	2.26
	Long-Term	5.00	1.90	5.88	2.30
Information token questions (/10)	*Pre-Game*	1.41	1.84	2.59	2.29
	Post-Game	5.47	2.40	5.82	3.03
	Long-Term	5.27	1.95	5.38	1.19

Table 11. Mean and standard deviations of test scores for the two experimental groups

The mean and standard deviations of the pre-game, post-game, and long-term test scores for both story questions and information token questions, shown for both experimental groups.

It was observed that many participants had greatly varying pre-game levels of knowledge, therefore a more generalisable measure of knowledge gain was required. For this purpose, "conversion rates" were calculated as, for the questions where the corresponding information was encountered in the game, the percentage of those questions where knowledge gain was observed between the pre- and post-game answers. This concept is explained in Figure 32, and the distributions of conversion rates for the story questions and information token questions are shown in Figure 33. Comparisons of conversion rates between 3D Environment and Constrained Environment groups were performed. For the story questions, a Shapiro-Wilk normality test was performed and neither the 3D Environment group, $W(17) = 0.94$, $p > 0.05$, nor the Constrained Environment group, $W(17) = 0.92$, $p > 0.05$, were significantly non-normal. Levene's test was performed on the untransformed means and the variances for the two test conditions were equal, $F(1, 32) = 0.06$, $p > 0.05$. Therefore, an independent t-test was performed, and the difference was not significant, $t(32) = 0.68$, $p > 0.05$, with confidence intervals of between -0.10 and +0.21. For the information token questions, a Shapiro-Wilk normality test was applied and neither the 3D Environment group, $W(17) = 0.91$, $p > 0.05$, nor the Constrained Environment group, $W(17) = 0.93$, $p > 0.05$, were significantly non-normal.

Levene's test was performed and the variances for the two test conditions are equal, $F(1, 32) = 0.87$, $p > 0.05$. Therefore, an independent t-test was performed, and the difference was not significant, $t(32) = 1.30$, $p > 0.05$, and the t-test confidence intervals were between -0.08 and +0.36.

Test Answers		Post-Game Test Answer: **Correct**	Post-Game Test Answer: **Incorrect**
Pre-Game Test Answer	**Correct**	No Knowledge Gain Needed	Knowledge Loss
	Incorrect	Knowledge Gain	No Knowledge Gain

Key	
(green)	Positive Outcome
(red)	Negative Outcome

$$\mathit{Conversion\ Rate} = \frac{\#Positive}{\#Positive + \#Negative}$$

Figure 32. Constrained environment experiment conversion rate calculation

Explanation of how conversion rates are calculated for the Mesopotamian history test scores, based on the pre-game and post-game test answers.

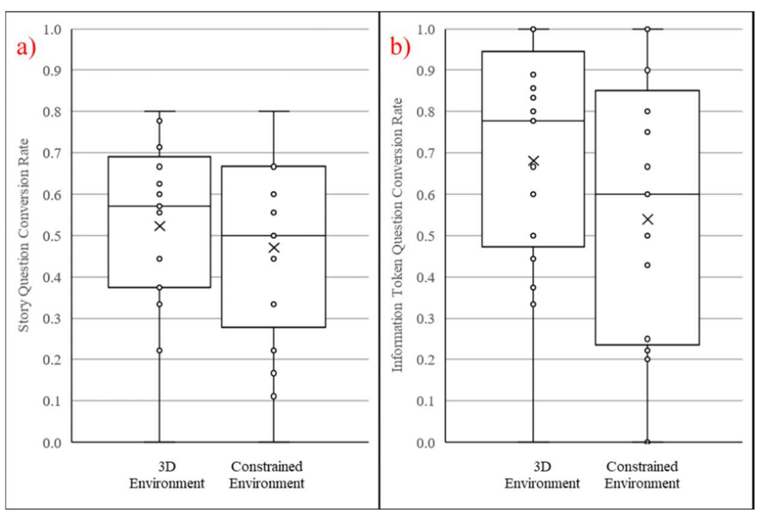


Figure 33. Conversion rates for the two experimental groups for each set of test questions

a) Box-and-whisker plots of the conversion rates for the story questions of the Mesopotamian history test, shown for the 3D Environment and Constrained Environment experimental groups; b) box-and-whisker plots of the conversion rates for the information token questions of the Mesopotamian history test, shown for the 3D Environment and Constrained Environment experimental groups.

For the knowledge gain that occurred between the pre-game and post-game stages, the percentage of this knowledge gain that remained at the 3-month long-term stage was measured, based on the long-term test answers, referred to here as the "retention rate". Retention rates are shown for the two experimental groups, for both story questions and information token questions, in Figure 34. Comparisons between the two experimental groups were then performed. For the story questions, a Shapiro-Wilk normality test was performed, and the 3D Environment group, $W(16) = 0.90$, $p > 0.05$, was not significantly non-normal, but the Constrained Environment, $W(16) = 0.77$, $p < 0.05$, was. Therefore, a Mann-Whitney U test was performed, and the story retention rate amongst the two groups did not differ significantly, $U = 115.50$, $z = -0.49$, $p > 0.05$, $r = -0.09$. For the information token questions, a Shapiro-Wilk normality test was performed, and both the 3D Environment group, $W(16) = 0.86$, $p < 0.05$, and the Constrained Environment group, $W(15) = 0.81$, $p < 0.05$, were significantly non-normal. Therefore, a Mann-Whitney U test was performed, and the information token retention rate amongst the two groups did not differ significantly, $U = 113.50$, $z = -0.26$, $p > 0.05$, $r = -0.05$.

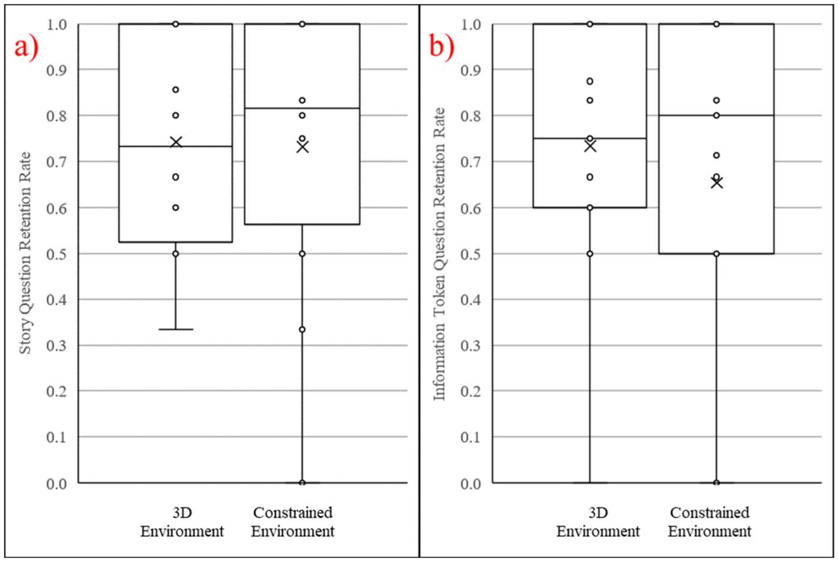


Figure 34. Retention rates for the two experimental groups for each set of test questions

a) Box-and-whisker plots of retention rates for the story questions of the Mesopotamian history test, shown for the 3D Environment and Constrained Environment experimental groups; b) box-and-whisker plots of the retention rates for the information token questions of the Mesopotamian history test, shown for the 3D Environment and Constrained Environment experimental groups.

During the interviews, 15% of all participants (18% 3D Environment group, 12% Constrained Environment group) mentioned that they prefer to learn through naturalistic interactions rather than through direct (textual) information. CP03 described this as follows: "When you were talking to people there [in the market] that's when you learned the most, as opposed to just getting, like, block text". Additionally, one participant in the control group, CP05, noted learning information directly from the layout of the environment: "It was interesting, you got a sense of the size differences, for the big temple, it seemed to me that it might be, like, a focal point for the community because it was right on top of the hill, and it took a while to go all the way round it". Finally, some participants showed clear signs that the nature of the experiment influenced the way they played the game. Participant TP10 said that the pre-game test questions had made them want to collect more infonodes in the game. During playing, participant CP10 said aloud "I've learned a lot of the answers to the questions I was asked… but I guess that's the point really", showing the priming effect of giving participants a pre-game test.

5.3.6. Comparison of Post-Game Interest

At the three-month follow-up stage of the experiment, 10 out of 17 participants (59%) in the 3D Environment group and 9 out of 17 (53%) in the Constrained Environment group stated that they had either sought out further information on Mesopotamian history or were planning to do so. These results are shown in Figure 35. A Pearson Chi-Square test found no significant association between the experimental group the participants were assigned to and whether the participants took further steps to learn more, $\chi^2(1) = 0.12$, $p > 0.05$. Of those who said they had or would learn more, the most common method of finding further information was reading web pages, although participants also mentioned books, documentaries, podcasts, and museum visits. To determine the factors that would encourage a participant to seek more information on the subject matter, a set of bi-serial correlations were performed, shown in Table 12.

Variable 1	Variable 2 (Binary)	Test	Test Value	Significance
Initial familiarity with subject	Pursued further information	Spearman's Rho	$r_s = 0.16$	$p > 0.05$
Enjoyment of the game	Pursued further information	Spearman's Rho	$r_s = 0.02$	$p > 0.05$
Post-game interest increase	Pursued further information	Spearman's Rho	$r_s = 0.36$	**$p < 0.05$**
Long-term interest increase	Pursued further information	Spearman's Rho	$r_s = 0.55$	**$p < 0.05$**
Mean game score	Pursued further information	Pearson's R	$r = 0.22$	$p > 0.05$
Mean presence rating	Pursued further information	Pearson's R	$r = 0.04$	$p > 0.05$

Table 12. Bi-serial correlations of experimental variables with pursuit of further information

Bi-serial correlations between different experimental variables and whether or not participants pursued further information on the serious game subject matter after the experiment was concluded, for all participants in both experimental groups. Reprinted from Hanes and Stone (2019).

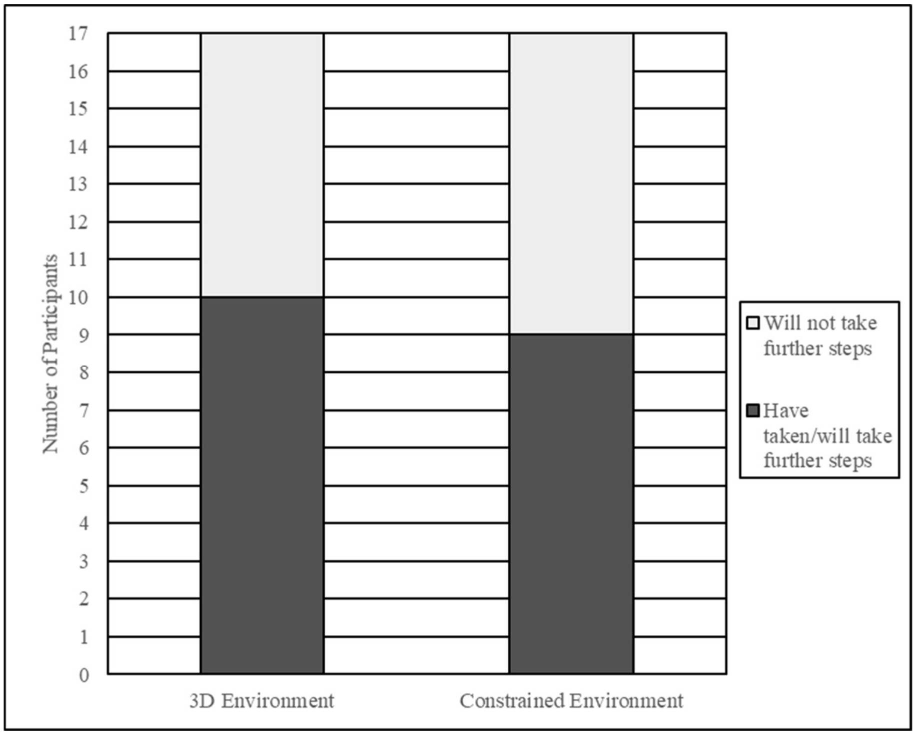


Figure 35. Post-game steps taken to learn more for the two experimental groups

The numbers of participants who said they had, or planned to, take further steps to learn more about Mesopotamian history after taking part in the experiment, for both the 3D Environment and Constrained Environment experimental groups. Reprinted from Hanes and Stone (2019).

5.3.7. Observations and Interview Responses

While participants were playing the game, their in-game and real-life behaviours were silently observed. A general observation was that the participants in the 3D Environment group seemed to immediately recognise the tropes of the game and how to interact with them. Participants in the Constrained Environment group, however, had a greater learning curve to undergo and it took longer before they were as visibly comfortable and proficient at interacting with the game.

Participants' views of the game seemed (perhaps unsurprisingly) to be influenced by their expectations of modern games and by other games they play. During the experiment, one participant, CP03, compared the graphics of the 3D Environment unfavourably to older hardware and games: "it's very 'Goldeneye', isn't it?". During the interviews, another participant from the 3D Environment group, CP10, stated that they are used to games such as Assassin's Creed and that this game was not what they were expecting, it was "different in many ways".

Finally, during the post-game interviews, participants were asked for their most and least favoured aspects of the game they played, and the results are shown in Table 13.

Game Aspect	One of Most Favoured Aspects			One of Least Favoured Aspects		
	3D Environment	Constrained Environment	Overall	3D Environment	Constrained Environment	Overall
Tablet puzzle	1/17 (6%)	2/17 (12%)	9%	0	1/17 (6%)	3%
Time pressure	4/17 (24%)	1/17 (6%)	15%	0	2/17 (12%)	6%
Graphics	1/17 (6%)	2/17 (12%)	9%	3/17 (18%)	3/17 (18%)	18%
Voices	3/17 (18%)	0	9%	2/17 (12%)	6/17 (35%)	24%
Market interactions	4/17 (24%)	4/17 (24%)	24%	0	0	0%
Learning information	9/17 (53%)	10/17 (59%)	56%	0	0	0%
Character movement	0	0	0%	11/17 (65%)	0	33%
Navigation	0	0	0%	3/17 (18%)	4/17 (24%)	21%
No music or ambient sound	0	0	0%	3/17 (18%)	2/17 (12%)	15%

Table 13. Participant most and least favoured game aspects

Participant interview responses when asked for their most and least favoured aspects of the game they played, shown for each experimental group. Reprinted from Hanes and Stone (2019).

5.3.8. Effects of Participant Characteristics

An additional set of analyses were performed to examine the effects of participant characteristics, namely gender, educational discipline, and frequency of playing videogames, on each of the participant results. Due to the somewhat tangential nature of these investigations, they are shown in Appendix II, and the subsequent results are shown in Table 14.

Participant Characteristic	Results	Discussion
Gender	Female participants had significantly higher enjoyment of the game than male participants.	This result emphasises the need for careful target audience selection, and design and evaluation directed towards the target audience, including focus testing with a representative sample of participants.
Educational discipline	Participants from a history background had a higher initial familiarity with and level of knowledge of the subject matter pre-game, when compared with participants from other backgrounds. They did not have significantly different conversion rates for story questions, but they did have significantly higher conversion rates for information token questions.	This result provides evidence that when the information is more closely integrated with the gameplay, as is the case for the story questions, it is more effective at teaching players from different backgrounds with different skills. When the information is presented only through text and is less integrated with the gameplay, as is the case for the information token questions, the effectiveness of learning is more dependent on the interests and capabilities of the player.
Game-playing frequency	Participants who play video games less frequently gave the games higher scores, and they had significantly lower conversion rates, both for story and information token questions	The first result may be caused by participants who play games less frequently having lower expectations of the games they play. The second result may be caused by the game mechanics creating more cognitive load for less experienced players, allowing less capacity for engagement with the material and learning. Both results stress the importance of clearly defining the target audience and their familiarity with videogames.

Table 14. Summary of experimental investigations into effects of participant characteristics

A summary of the results and discussions resulting from three smaller investigations into the effects of the participant characteristics on the experimental results. These investigations are shown in Appendix II.

5.3.9. Museum Expert Interview

An individual from Arts Council England was invited to play the constrained environment game and be interviewed to help determine the feasibility of implementing such games within physical museum displays. They had worked in Museum Insurance and Accreditation for six years, involving visiting museums across the country, and were actively interested in how museums use technology and interactive displays. They remarked that when technology is implemented well in museums, it is implemented very well indeed and can be highly successful.

Overall, they felt very positive about the idea of implementing a game such as the constrained environment implementation of Discover Babylon in a museum space. They are very supportive of using games in museums, because they must adapt to and reflect the public that they serve. They believed that the greatest challenge of implementing any games would be the resources required. For a museum, this cost must be considered for the entire lifecycle of the game, for equipment, design, development, and maintenance. There is interest and appetite for games among museums in the UK. However, austerity cuts and staff shortages make their use more difficult. The other principle challenge is the tone of the game, that the game is targeted at the same audience in the same manner as the rest of the museum displays. The game should be well-integrated into the rest of the museum, and not simply an add-on. This, of course, depends on the style of the museum and the tone they are trying to achieve.

5.4. Discussion

5.4.1. Discussion of Experimental Design

As was described in Section 5.2.2, the experimental procedure was designed with two experimental groups, comparing the 3D environment against the constrained environment. This meant that the results, particularly for learning, could not be compared against an equivalent traditional form of learning, for example paper-based resources. However, the focus of the experiment was to determine whether a difference exists between the two environment types, rather than an evaluation of the serious game for heritage, therefore it is considered likely that not much additional insight would have been gained by performing this type of three-group experimental design. Furthermore, such a design would have also further split the number of participants, resulting in fewer participants per experimental group, having an adverse effect on the power of the experiment.

Another possible experimental design mentioned in Section 5.2.2 was a repeated samples design, where each participant would have been asked to play both versions of the game. While this would have removed effects of participant characteristics on the results, it also would have introduced side-effects due to the order with which participants played the two games. Furthermore, one can likely not expect to gain reliable measures of participant enjoyment of a level when they must play it twice in short succession. Finally, such an experimental design would have also precluded the long-term aspect, where participant knowledge gain was measured three months after the initial experiment.

Finally, it was decided that the experimental design should utilise different interaction modes for the two versions of the game; keyboard for the 3D environment and mouse for the constrained environment. This is considered to have been an advantageous decision, because none of the participants reported having any difficulties with the mode of interaction. Furthermore, to test the interaction mode as an additional independent variable in an independent samples design would have meant splitting the participants between four groups instead of two, greatly reducing the number per group, and so the power of the experiment.

5.4.2. Discussion of Presence

Mean presence ratings amongst the Constrained Environment group were marginally higher than those in the 3D Environment group, but not significantly so. Furthermore, the 95% confidence intervals are relatively narrow, signifying the 3D environment version of the game is no more than 0.65 points better than the constrained environment on the Slater-Usoh-Steed presence scale. Additionally, the interview responses suggested the constrained environment could create a strong sense of a historical place, if it engages participants emotionally, an observation supported by prior research (Zhang, Perkis and Arndt, 2017). However, the range of different responses to the topic of presence and immersion in the interviews show the complexity of these concepts and how people can understand the terms differently, highlighting the importance of using standardised instruments such as the Slater-Usoh-Steed questionnaire.

Therefore, hypothesis $H_{A,0}$ was not rejected and still stands, that "the level of presence experienced by participants while playing the serious game for heritage utilising a 3D environment is the same as participants while playing the SGH utilising a constrained virtual environment".

5.4.3. Discussion of Perceived Game Quality

The mean game scores were higher for participants in the 3D Environment group, although not significantly so. Again, the 95% confidence intervals were relatively narrow, signifying the 3D environment game is perceived as being no more than 1.37 points better, on a scale out of 10, than the constrained environment game. It is also interesting that mean game score and enjoyment are both significantly correlated with mean presence, however it is unclear what the direction of causality is. Presence could lead to enjoying the game more, or enjoyment could lead to increased presence, or a third factor could be causing both.

Therefore, hypothesis $H_{B,0}$ was not rejected and still stands, that "enjoyment and perception of quality amongst participants while playing the serious game for heritage utilising a 3D environment is the same as participants after playing the SGH utilising a constrained virtual environment".

5.4.4. Discussion of Information Token Collection

Participants collected significantly more information tokens in the constrained environment than in the 3D environment. It is believed this is due to movement within the 3D environment being inherently slower and finding the information tokens in the constrained environment being easier, by exhaustively visiting every scene. Furthermore, some of the tokens in the 3D environment were placed in locations that required skilled control of the character to reach, which caused some participants to simply give up. Despite this, many of the participants felt they wanted to collect all the tokens. Indeed, participants seemed to be split into two groups; those who attempted to collect all the infonodes, no matter how good or bad they thought the game was (the self-described "completionists"), and those who collected infonodes in correlation with how good they found the game. This desire to complete collection tasks with only intrinsic rewards is an interesting phenomenon that should be utilised more as a source of motivation for completing serious game learning activities. Finally, there were also some participants who said they had wanted to collect all the infonodes, but who did not. Some of these participants said that they had wanted to collect more but had accidentally ended the level prematurely, because the level is ended by pressing a button, without an option to cancel if the button was pressed accidentally. Therefore, by changing this aspect of the game, which can be regarded as a basic design flaw, these participants could have been exposed to more informative content.

Therefore, hypothesis $H_{C,0}$ was rejected, and the alternate hypothesis $H_{C,1}$ must now stand instead, that "the number of information tokens collected by participants while playing the serious game for heritage utilising a 3D environment is different from participants while playing the SGH utilising a constrained virtual environment".

Despite participants in the Constrained Environment group collecting significantly more information tokens, it was observed that those participants did not achieve significantly higher learning through the information tokens, and instead achieved lower (though not significantly lower) conversion rates for these questions. This suggests that collecting more information tokens does not necessarily lead to improved learning, which is supported by the observation that several participants would be motivated to collect the tokens but would not be interested in reading the information in them. Therefore, while collection activities can create inherent motivation for completing tasks, the learning activities must still be designed to be engaging and integrated with the gameplay, lest they be simply ignored.

5.4.5. Discussion of Learning

Overall, it is encouraging to see the extent to which most participants' test scores were increased in the post-game test, and how high many of these scores stayed at the long-term stage. This shows the potential effectiveness of Discover Babylon as a serious game for education, however the game was not tested against an equivalent traditional means of education, as has already been discussed. The concept of "conversion rates" was introduced to normalise for the differing pre-game scores, and the conversion rates for the two sets of test questions were not significantly different between the two groups, however the confidence intervals for both tests were rather wide, meaning there is less confidence that constrained environments can indeed achieve the same level of learning as 3D environments. This aspect therefore requires more investigation in the future. For the retention rates for both sets of questions, there were no significant differences between the two experimental groups. However, due to the nature of the data, parametric tests were not performed, so it is more difficult to be confident of the accuracy of this negative result. Once again, this aspect requires further investigation.

In this experiment, pre-game tests were an important feature of the experimental design, allowing calculation of conversion and retention rates, despite the varied pre-game levels of knowledge. However, as was seen from some participant responses, the application of pre-game tests had some priming effects, as was also investigated by All *et al.* (2017). Some attempts were made to mitigate these effects, such as altering the question order and introducing irrelevant questions, however the use of pre-game questions is a difficult issue which must be carefully considered, for which All *et al.* (2017) give further suggestions.

Therefore, hypothesis $H_{D,0}$ was not rejected and still stands, that "knowledge gain amongst participants playing the serious game for heritage utilising a 3D environment is the same as participants playing the SGH utilising a constrained virtual environment".

5.4.6. Discussion of Post-Game Interest

There was no significant difference in the rates with which participants from the two groups took further steps to learn more about Mesopotamian history after the experiment. It is also encouraging to see how many participants took such steps, and the wide range of stated activities, when this was a completely voluntary activity. Based on the point-biserial correlations, the rate of taking further steps was only correlated with post-game interest in the subject matter, which in turn was not found to be correlated with any of the game characteristics. Therefore, it seems that whether participants wanted to learn more was dependent on their own personal interest in the material rather than the features of the game. From a serious game development perspective, this is a disappointing conclusion, however it is still one that can inform the development process. However, due to the lack of correlation between initial familiarity and whether participants took steps to learn more, it could be concluded that the game was somewhat effective at introducing participants to subject matter they were not familiar with and inspiring them to learn more.

Therefore, hypothesis $H_{D,0}$ was not rejected and still stands, that “interest in the subject matter and voluntary pursuit of more information amongst participants after playing the serious game for heritage utilising a 3D environment is the same as participants after playing the SGH utilising a constrained virtual environment”.

5.4.7. Discussion of Observations and Interview Responses

Overall, there were some positive responses to the constrained environments, specifically its parallax effects. However, for some participants the constrained environment clearly did not recreate the experience of a 3D environment. It was also apparent that participants felt less comfortable and familiar with the interactions of the constrained environment. It might therefore be advisable to pay additional attention to the onboarding section of the game in a constrained environment, where the player is gradually taught the interactions and mechanics through hints or tutorials. There were also issues with participants not knowing what to do, what items to trade for, or what they could interact with, with both versions of the game. While this might be a conscious decision of the designers to require the participants to actively explore the environment and the possible interactions, having more notifications of the player’s current objectives may help to reduce uncertainty and frustration. Additionally, a map may well have also reduced this frustration and improved the issues of difficult navigation. Finally, there were also some participants in the Constrained Environment group who were unaware that they were represented by the player avatar. This may be due to the lack of visible feedback in the avatar when interacting with the environment, or may also be due to players experiencing a reduced sense of embodiment in their avatar when using a third-person perspective (Gorisse *et al.*, 2017).

As was expected, participants' expectations of the serious game are clearly influenced by the commercial games they play. However, this is an unavoidable fact of serious game development, and it is proposed that constrained environments, by utilising graphics less similar to high-fidelity 3D commercial games, might reduce unfavourable comparisons. Furthermore, 3D graphics are quickly superseded by the new state-of-the-art and serious games utilising such environments have a shorter lifecycle, as the participant's unfavourable comparisons with old gaming technology, such as the Nintendo 64, show.

It was apparent that many aspects of the game's design were divisive, which some players liked and some disliked, although this was seen in both the 3D and constrained environment versions of the game. A typical approach to address this issue may be to simply introduce more variety and optional content into the game. However, this approach will likely require more development resources, so a sensible balance must be reached. It is also encouraging that over half of the participants stated that learning was one of their favourite aspects. Finally, ambient sound and music is one aspect of virtual environments that can be overlooked within the development process (where programming and visual assets can take precedence) yet is an important aspect of presence (Serafi and Serafi, 2004) and its absence is noticed by players, as was observed.

5.4.8. Manifestation of Historical Content

In the original Uruk level of Discover Babylon, most of the manifestations of historical content take the form of 3D models of buildings and objects, with textual descriptions of their significance, related historical activities, or historical actors. There are also some manifestations presented through aural verbal and mechanical form, where the player must interact with traders at the market, engaging in dialogue and trading goods. In the constrained environment implementation of the level, the only aspect of the historical content that was different was that the 3D models were instead 2D images, whereas all other aspects of the content were kept the same.

However, based on there being no significant differences in participant learning between experimental groups, it could be concluded that there was no evidence of the different content types between 3D and constrained environments influencing participant learning. However, one participant in the 3D Environment group noted learning information directly from the layout of the environment. It is therefore important to consider whether the constrained environment was as effective at transmitting this type of spatial information that is implicitly manifested within the layout and geometry of the 3D models. This type of information is often difficult to account for with traditional text-based test questions (Pujol and Economou, 2008), and requires an approach specifically suited for measuring the transfer of spatial information, such as that used by Debailleux *et al.* (2018). This is one potential avenue for future research with presenting constrained virtual environments for history learning.

However, participants did express certain preferences for different types of historical content in both environments. It was clear that participants were not keen on having to stop to read large amounts of text while playing. Instead, participants said they favoured learning through naturalistic interactions, integrated into the game's mechanics. This was especially the case in the market trading segment of the level, where the participants learn through engaging with NPCs in dialogue and trading of goods, which many participants said they enjoyed.

This evidence, in turn, also supports the notion that the history learning in an SGH should be meaningfully integrated with the gameplay. Not only does it better support the learning activities as other researchers have proposed (Perrotta *et al.*, 2013; Ke, 2016), and better supports learning for participants from different educational disciplines (as seen in the results comparing participant disciplines in Section 5.3.8), but players clearly prefer it too.

5.4.9. Discussion of Museum Expert Interview

Many of the points raised by the museum expert could equally apply to other (non-constrained) virtual environments and serious games implemented in museum contexts, however the fact that they identified limited budgets and resources as the greatest challenge confirms the necessity of the current research approach. Furthermore, it was also encouraging to hear their positive reaction to the constrained environment, and to the notion of implementing such games in physical museum displays. The expert's comments on matching the tone of the game to the surrounding museum displays is also informative, showing the importance of keeping the directions of design closely aligned. However, there was no discussion of the game being implemented within a digital setting, such as a museum website, since the expert's experience was only with physical displays.

5.4.10. Compilation of Guidelines for Designing Constrained Virtual Environments for Serious Games for Heritage

By considering all the experiences of designing the constrained environment, conducting the experiment, and the issues encountered, it is possible to begin drawing together a set of design guidelines for constrained environments in SGsH. Since the implementation of the constrained environment was only focused on setting and navigation, and the informational content was recreated without alteration, the guidelines correspond to the first two stages of Ibrahim & Ali's (2018) model, namely "environment setting" and "navigation mechanism". The guidelines are shown in Table 15, categorised according to these two stages. Where possible, each guideline is shown adjacent to the corresponding issue encountered throughout the design and experimentation processes. It must be stressed that these guidelines are not intended to be a formal theoretical framework, but rather supplement such a framework for the SGH design and development process.

Observed Issue	Design Guideline	In-Game Example
	Environment Setting	
Some participants had difficulty navigating and getting to where they wanted to go. Some participants could not achieve a sense of spatial awareness and visualise where they were in the environment.	Show large, recognisable landmarks in multiple scenes, so that players can build up a sense of the environment and navigate relative to those landmarks.	Large natural features or architecture are effective for this. In the Uruk environment, the Ziggurat and temple were tall, dominant buildings in the centre of the map. Showing these in the background of as many scenes as possible may help players to navigate, using them as reference points.
Some participants found that every part of the environment looked too similar, in style and colour.	Make different segments of the environment look (and sound) unique, so that players can more easily recognise where they are. This will also add more variety and interest to the environment.	Make each segment of the environment unique using different environmental colour palettes, NPCs, litter objects, and ambient sounds, depending on what is most appropriate for the historical material. Also ensure that no two scenes look too similar and could be confused for one another.
Some participants found the environment too "quiet" and "empty".	Maximise the use of NPCs, litter objects, and ambient sounds throughout the environment.	Populate the environments with NPCs who would live or work there, objects that would be used there, and the sounds of the activities carried out there.
	Take advantage of constrained environments' ability to suggest detail without showing it exhaustively.	A busy scene of people and activities can be suggested by only showing glimpses of it, or shown in the background, accompanied by relevant ambient sounds.
Some participants found the graphics too "static" or not "dynamic" enough. Some participants found the graphics too "flat" or not "3D" enough.	Maximise the use of depth layering, thereby maximising parallax and depth of field effects, and chiaroscuro lighting within each scene.	Use many layers at different distances from the camera and maximise differences in lighting with bright light sources and shadows. However, ensure that layers cannot overlap each other in illogical ways as they move through parallax.
	Maximise the use of animated objects within each scene.	Add animations to background objects, such as moving water or cloth that moves in the wind.
–	Design the environment to take advantage of players' curiosity and internal motivation to explore.	Design each scene so that the transitions to other scenes invite curiosity and preferably infer an interaction with the environment, e.g. walking up a set of stairs or opening a door.
–	Scatter "collectibles" and "achievements" through the environment to encourage players to explore all of the content.	Track how many NPCs the player has talked to or how much information they have collected from the environment, and show this progress, indicating whether they have found everything.
	Navigation Mechanism	
Many participants had difficulty navigating and getting to where they wanted to go.	Consider carefully whether the player should be given additional cues to aid in navigation, such as a map, a compass, or an arrow pointing to the next objective.	These navigational aids can be shown permanently on the HUD or made visible with a button press. Such features should be carefully designed such that they do not reduce player desire to explore.
Many participants were unsure of their current objective, or what they should be doing.	Consider whether the player should be shown the current and completed objectives.	The objectives could be shown permanently or made visible with a button press. Objectives could also contain hints for what the player should do next.
Some participants found the changes of camera angle between scenes unnatural or wanted to control the camera.	Decide early on whether the scenes are equivalent to a 1st person or 3rd person perspective. Design each scene so that the position and angle of the camera corresponds logically to a person moving through that environment. Consider the effect of first- and third-person perspectives on players' sense of spatial awareness and ability to navigate (Gorisse *et al.*, 2017).	Draw a plan view of the environment, chart how a character might move through it, and design the camera placement for each scene to correspond naturally to this movement, without disorienting changes in position or angle.
Some participants were unaware that they were playing as their avatar.	If using a 3rd person perspective, the player avatar should be shown, able to move within and interact with the scene.	When the player interacts with an element in the scene, the avatar should then be shown moving to that element and interacting with it.
Many participants felt somewhat less comfortable with the constrained environment compared with 3D environments.	Gradually introduce the player to the mechanics for moving and navigating within the environment during an on-boarding segment. Hodent (2018) gives advice for the design of onboarding in video games from a user experience perspective.	This on-boarding segment could be a small, self-contained "starting area" of the environment where the player can learn and familiarise themselves with the mechanics before starting the main portion of the game.

Table 15. Initial guidelines for the design of constrained virtual environments for serious games for heritage

A set of early guidelines to direct and advise future researchers and developers in the design of serious games for heritage utilising constrained virtual environments, based on the experiences and issues identified through the development and testing of the constrained environment implementation of Discover Babylon. Adapted from Hanes and Stone (2019).

5.4.11. Limitations of the Experiment

There were several limitations of the experiment that must be considered when evaluating the results. Firstly, the number of participants who took part in the experiment was not high enough to provide conclusive evidence of the equivalence of 3D and constrained environments, but rather to have shown where future work can be directed. Furthermore, while the Slater-Usoh-Steed presence instrument produces quantitative, easily comparable data, there are clearly aspects of participants' experience of these historical places that cannot be measured only through spatial presence, though this is also an issue faced generally within the field.

Next, the test questions that were developed in cooperation with the field expert from the British Museum were designed to be unambiguous to mark, and therefore predominantly tested learning of simple facts. However, this may have limited the ability of the questions to measure the complex learning processes and meaning-making that takes place as the participant plays the game. It may have also affected the type of learning that was measured, since these types of traditional textual questions have only limited effectiveness at measuring learning of spatial information from within the environment (Pujol and Economou, 2008).

A matched-pair experimental design may have helped to mitigate the effects of differing levels of initial participant knowledge of the subject matter, by pairing participants based on their pre-game test scores, as was recommended by All *et al.* (2017). However, this was not possible to carry out due to logistical constraints of the experimental procedures, namely slow participant recruitment and high participant attrition rates. Some other advice for experimental design for testing serious games given by All *et al.* (2016) could not be followed, for example they recommend each experimental group having at least 20 participants, which could not be achieved.

It is also difficult to ascertain how far the results of the present study are generalisable to other serious games using different designs and presenting different historical fields. Some informational content may simply lend itself better to the constrained environment format, so the application of constrained environments must be carefully considered for each project in isolation. Furthermore, as discussed in Section 4.4.2, the constrained environment was developed with a specific visual style, selected due to development constraints and to reduce the comparability of the environment with a photorealistic representation. However, in the field of history, where accuracy and authenticity are a vital component of any manifested information, the extent to which serious games are allowed to diverge from representing information as accurately as possible must be considered very carefully.

Finally, the original Discover Babylon game was targeted at younger players up to 14 years old, however the experimental participants were all aged 18 or older, due to logistical constraints and the ethics required to perform experiments with minors. However, the purpose of the experiment was not to test the game within its target audience, but rather to test the principles of constrained virtual environments, and older participants allowed more detailed and articulate responses to be collected, especially in the interviews.

5.5. Conclusions

5.5.1. Chapter Conclusions

In this chapter, an experimental investigation was performed to compare a serious game for heritage utilising a 3D virtual environment against an equivalent serious game utilising a constrained virtual environment, the development of which was described in Chapter 4, to address the third secondary research question. Such a comparison was recommended by Turner *et al.* (2013), when they first proposed the theory and development of constrained virtual environments. The methodology for the experiment was described, including its independent samples two-group design, the experimental hypotheses, the measurements and observations made, the experimental procedures, and the participants and methods of recruitment. Results were given for each area of investigation, including the five sub-objectives of the experiment, relating to participant experience of presence, enjoyment and perception of game quality, exploration of the environments, learning from the serious game, and interest in the subject matter after playing. Results were also given, relating to observations made about participants as they played and their responses during the post-game interviews, and the effects of participant characteristics on the results. Results were also given for an interview with a museum expert who was invited to play the constrained environment version of the game and give feedback on the feasibility of implementing such SGsH in museum physical displays. A discussion of all of these results was held, culminating in a proposed set of guidelines and best practices to guide the development of constrained virtual environments for SGsH in the future, which are the first step towards forming a more comprehensive framework. Finally, the limitations of the experiment were also enumerated, drawing focus upon where the results may be less reliable or where further research is required.

The experimental results provided evidence that the constrained and 3D environments could achieve similar levels of presence and were perceived by players as being of similar levels of quality. Many of the participants felt intrinsically motivated to collect all the information tokens from within the environment, and participants collected significantly more from the constrained environment, likely due to the collection activity being inherently easier. Almost all participants showed an increase in cognitive knowledge of the subject area between pre-game and post-game tests, and much of that knowledge was retained at the 3-month stage. The two experimental groups were not significantly different regarding learning, however the error bounds of this similarity are quite large, so it is difficult to conclude whether or not learning was equally effective in both versions of the game. Many participants found that the game increased their level of interest in Mesopotamian history and were motivated to perform their own further learning, and participants who played the 3D or constrained environment were not significantly different in this regard. However, there were also several issues observed for the constrained environment, particularly related to environmental navigation, which can be improved through further developments. Comments from the participant interviews provided evidence for the advantages of play and learning being well-integrated, in terms of both player enjoyment and learning. Analysis of participant characteristics also supported this conclusion, as well as showing the critical importance of defining the characteristics of the target audience and designing the serious game accordingly. Finally, the interview with a museum expert provided positive feedback for the potential use of SGsH utilising constrained virtual environments within physical museum displays and confirmed that cost is the greatest challenge that must be overcome to implement such games.

Overall, to give a summary of the efficacy of constrained virtual environments for serious games for heritage, this experiment has not been able to conclusively prove the equivalence of constrained environments with 3D environments, however it has shown that there are similarities in the effectiveness of the two environment types at achieving their aims, and it can therefore be concluded that constrained virtual environments are an approach worthy of future research and further development, analysis, and experimentation.

5.5.2. Future Work

Future research in this field includes further experimentation with larger cohorts (of various ages and backgrounds) to determine to what extent constrained environments can convey historical places and their cultural context, compared with 3D environments. Such investigations could investigate participants' phenomenological experience of those historical places and should include analyses of learning effectiveness, especially spatial information that is manifested through the environment itself. Work could also address the effects of different visual styles, both photorealistic and non-photorealistic, within constrained virtual environments, their effects on player perceptions of game quality, historical accuracy and authenticity, and learning. Future research could also further investigate the use of hardware with different levels of sensory immersion and its effect on presence, sense of place, and perception of the constrained environment. Work should also address how historical information can be manifested differently through those different visual styles. Finally, future research should also design new serious games for heritage built upon the concept of constrained environments from the initial design phases. Researchers could consequently expand the guidelines presented in this paper, especially considering how historical information should best be designed and manifested through a constrained environment. This could address the final two stages of Ibrahim & Ali's (2018) framework (namely "Information Presentation" and "Information Design") and so would work towards a more complete framework for the design of constrained virtual environments for history learning.

5.5.3. Applications to the Thesis

Now that an initial evaluation of constrained environments applied to SGsH has been completed, later chapters in this thesis will be able to draw upon some of the conclusions of this chapter, particularly relating to the advantages and opportunities of constrained virtual environments. These can be applied to presenting Assyriology and Mesopotamian history effectively through serious games for heritage, especially when development budgets are more limited and unable to cover the costs of developing photorealistic 3D environments.

Chapter 6 Designing Serious Games for Assyriology

6.1. Introduction

6.1.1. Chapter Introduction

This chapter will partly address the fourth and final secondary research question, defined in Section 2.9.2, relating to how serious games should be designed for the field of Assyriology. It will draw upon the work detailed so far throughout the thesis and will discuss how the design of serious games for heritage might address the topics, artefacts, opportunities, and challenges specific to Assyriology, discussed with the field expert in Section 1.6. It will also suggest manifestations of historical content and approaches to the design of SGsH to help create serious games for effective learning and engagement within the field.

This chapter will then present an original methodology for the design and analysis of serious games for heritage to reinforce the notion of meaningful integration of play and learning, whereby the activities of playing and learning in the serious games are seamlessly integrated together, in such a way that it also supports user meaning-making. The methodology will be based upon activity theory and will also make use of the model of historical content in video games presented in Chapter 3. It will be designed to complement other conceptual frameworks and methodologies for the design and analysis of serious games, and it will be shown how the methodology can be applied to SGH design and evaluation processes. Finally, the strengths and limitations of this methodology will be discussed.

6.1.2. Statement of Published Work

Much of the work detailed in this chapter, particularly Sections 6.4, 6.5, 6.6, and 6.7, relating to the methodology for the design and analysis of serious games for heritage, was published in a journal paper (Hanes and Stone, 2018) with the current author as first author and the supervisor as co-author. Accordingly, there are some instances of reused images or text between these sections and the publication. It should be emphasised that the current author was responsible for the development of the work detailed in this publication, as well as writing the manuscript, with the supervisor taking an advisory role.

6.2. Applying Serious Game Design to Assyriology

6.2.1. Applying Serious Games for Heritage to Knowledge and Artefacts in Assyriology

As the field expert described in Section 1.6, the field of Assyriology contains a general lack of physical artefacts or structures, especially degradable ones, due to the conditions of the region. This factor is likely to make the visual presentation of ancient Mesopotamian environments more challenging and there will necessarily be more uncertainty in the material that is manifested. For example, if a virtual heritage environment depicts a Mesopotamian city, there is a level of ambiguity of how exactly the streets and buildings should appear and sound. Therefore, approaches for presentation of environments that can include and naturally display the level of historical certainty would be promising, such as the constrained virtual environments described in Chapter 4. In the given example, a constrained virtual environment depicting the ancient Mesopotamian city could present the buildings and streets as vague outlines that are recognisable as buildings but not giving exhaustive detail.

However, as the field expert also described in Section 1.6, there are many surviving artefacts of distinct types, most notably clay cuneiform tablets, which provide a large source of potential information for SGsH to draw upon. The most direct way to manifest this information would be through photos, 2D images, or 3D models of cuneiform tablets, and systems for photographing and even creating, analysing, and visualising 3D scans of cuneiform tablets are now well developed (e.g. Woolley *et al.*, 2001; Anderson and Levoy, 2002; Hameeuw and Willems, 2011; Collins *et al.*, 2017). As suggested in Section 4.5.5, these 2D or 3D manifestations could be overlaid on top of the constrained virtual environments. However, as Tan and Rahaman (2009) argue, digital heritage objects will not have intrinsic meaning, especially when viewed by non-expert members of the public. The objects must be imbued with meaning, and this may be especially true for cuneiform tablets within serious games. This is due to the fact that their meaning and interest is to be found in the language engraved into them, most of all how and why they were written, what purposes they were written for, and what subjects they describe. One concept that links these aspects together is that of historical activity; the activities of writing the tablets, using the tablets, and the activities that they describe. Therefore, it can be concluded that the field of Assyriology for serious games is particularly dependent on how historical activity can be effectively manifested through the game. This concept of designing SGsH around historical activity will be further developed into a full design methodology later in this chapter.

6.2.2. Applying Serious Games for Heritage to Modern Archaeological Activities in Assyriology

As the field expert described in Section 1.6.3, the field of Assyriology contains many modern archaeological activities aimed at reconstructing knowledge of the period, including joining fragments of cuneiform tablets and fragments of texts. This therefore presents another instance where presenting the field of Assyriology through serious games is dependent upon the notion of manifesting activity, although in this case it is analytical heritage information rather than tangible, intangible, or natural heritage. Again, this concept of manifesting historical activities in SGsH will be developed into a methodology for design and analysis in this chapter. The concept of the player reconstructing modern historical knowledge of the period through the SGH game mechanics, and the potential interplay between this and the historical environments themselves and how they are presented, is an interesting one. This is especially true if the learning outcomes focus on modern historical practices and the concept of historical uncertainty, rather than only presenting the past as accurately as possible.

6.2.3. Overcoming Challenges in Serious Games for Assyriology

As the field expert described in Section 1.6.4, one of the greatest challenges serious games for Assyriology would need to overcome is the fact that most members of the general public have very low levels of background knowledge of the subject matter when coming into contact with information on Assyriology and ancient Mesopotamian history. Therefore, such SGsH must be very conscious of this fact and not assume any previous knowledge or familiarity with the subject matter. However, this challenge may also have a positive side, whereby serious games presenting information on Assyriology can make better use of the sense of discovery and wonder that many players may experience when encountering the period and subject matter for the first time.

6.2.4. Exploiting Opportunities in Serious Games for Assyriology

In Section 1.6.4, the field expert also described some of the potential opportunities for applying serious games for heritage to field of Assyriology, whereby people immediately desire more experiential information when learning about ancient Mesopotamia. They want to experience for themselves what the cities, buildings, and artefacts looked like and what the different languages of Mesopotamia sounded like. This response is very promising from the perspective of applying serious games and especially virtual environments to the field, which aim to present the subject matter in an experiential manner and so can achieve high levels of engagement for players. However, there are also issues of the level of historical certainty of the information being presented, which were also discussed in Section 1.3.4.

In Section 1.6.5, the field expert described a promising approach they foresaw in the application of serious games to Assyriology, namely that they should aim to show the subject matter through the perspective and comprehension of people at that time, who would have seen their world with a belief set and understanding that are completely different from our own. This approach is very promising for serious games aiming to increase players' empathy and understanding of people in a different period of time and suggests a greater exploration of how information can be manifested through serious game mechanics and procedurality. Such an approach is identified as an important approach for future research.

6.3. Methodology Aims and Approach

6.3.1. Aims of the Methodology

As was discussed in Chapter 2, the literature review of conceptual frameworks and methodologies for analysis and design of serious games revealed that the current state-of-the-art is somewhat insufficient for the specific needs of serious games for heritage, and Assyriology in particular. This was because there were very few frameworks that specifically addressed the history field and its unique requirements and challenges, and because none of the reviewed frameworks addressed the presentation of activity, which was identified in Section 6.2 as an important aspect for Assyriology. Furthermore, one concept that is important for the design of serious games for heritage is that of meaningful integration of play and learning, which was also not addressed by the frameworks and methodologies covered in the literature review in Chapter 2. Finally, the reviewed frameworks and methodologies were also insufficient in that they typically give very little guidance for the low-level processes of designing serious game elements, content, and mechanics for a given set of learning outcomes. For example, Carvalho *et al.* (2015) state that when using ATMSG for serious game design, "the designer produces a first version of the game prototype, using his or her preferred method", with no details of how to go about this. Bergeron (2006) is equally vague about this process, simply stating that ideas should "percolate in a designer's head until it's ready for the real world".

Therefore, in this section a methodology will be proposed that will assist the design process for serious games for heritage, as well as the processes of analysis and evaluation. Several other serious game frameworks focus on the integration of learning and play, for example, ATMSG

(Carvalho, Bellotti, Berta, *et al.*, 2015), LM-GM (Arnab *et al.*, 2015), and the framework presented by Hall *et al.* (2014). However, these approaches do not ensure that this integration of play and learning supports user meaning-making. For example, one could imagine two designs for a serious game for heritage based on the learning outcome of teaching players about a specific historical activity. In the first, the player might answer numerous detailed and in-depth questions about the historical activity, and their total score could be measured, and feedback given for how the player might improve their knowledge. In the second, the player could carry out the historical activity for themselves through the game mechanics and explore the possibility space of the activity in an experimental and experiential manner. One would likely conclude that the second design is superior because it allows exploration of the historical activity through game mechanics that represent real historical activities, actions, and decisions, resulting in a greater capacity to create and explore personal meanings for the player. However, the mentioned SG frameworks are unable to offer much insight into this difference. Therefore, the proposed methodology will utilise this notion of "meaningful exploration of historical activity". The methodology is best used alongside other serious game frameworks, because it only adds additional information and insight to the design process, without applying limits or restrictions which might preclude other approaches.

6.3.2. Methodology Approach

It has been proposed that the aim of a methodology for designing and analysing serious games for heritage should ensure that the integration of play and learning in the SGH supports user meaning-making. This aim is closely in line with the suggestions of Tan and Rahaman (2009), that digital heritage artefacts presented through virtual heritage applications will not carry any inherent meaning for the user, but must be imbued with meaning through the design process.

Having reviewed the literature around the design of serious games for heritage and the use of technology to enhance user experiences in museums, a model presented by Kaptelinin (2011) was selected as the most appropriate to form the basis of the methodology for the design of SGsH. The selected model uses the concepts of activity theory and "activity context bridging" to underpin the use of ICT in enhancing museum visitor experience when viewing artefacts to maximise their meaning-making. It defines activity context bridging as "through observation, imagination, inquiry and/or physical interactions, visitors [opening] up their activity contexts and reach out to meanings, values, and personal experiences revealed through understanding [artefact]-related activity contexts", arguing that this process should be facilitated through the use of technological means and giving advice for how to carry this out. It is proposed that a serious game for heritage can be seen as a similar technological means for facilitating such activity context bridging and meaning-making, therefore the model presented by Kaptelinin (2011) is a sound basis upon which to build the methodology for SGH design and analysis. To be able to give more detail on the methodology and this model of activity context bridging, it is necessary to first give some brief background information on activity theory, which will be covered in the next section.

6.4. Background on Activity Theory

Activity theory, also known as "cultural historical activity theory", originated in Soviet psychology but has now expanded into a wide-ranging field. For some of the more recent information on activity theory, in particular its application to ICT systems and HCI, the reader is referred to Kaptelinin & Nardi (2006) and Igira & Gregory (2009). The most basic unitary element of activity theory is the activity context triangle, shown in Figure 36, which consists of a subject who carries out an activity by interacting with an object using mediating tools, which are either external (such as physical tools) or internal (such as plans and mental models).

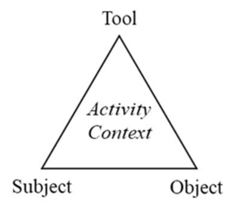


Figure 36. The activity context triangle

The activity context triangle is the basic unit of activity theory.

Leontiev (1978) proposed that activity has a three-layered structure, whereby an activity is directed by a motive, which may or may not be known to the subject, and that activity is made up of several actions, each of which is performed according to a known goal, and each action is made up of several operations, each of which is constrained by certain conditions. This three-layered structure is shown in Figure 37.

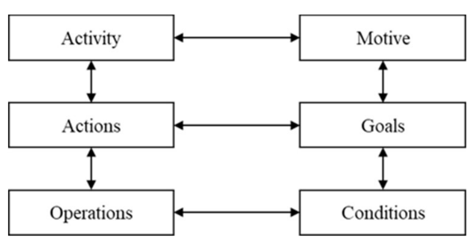


Figure 37. The three-layered structure of activity

Activities are directed by a motive and are made up of actions, performed to achieve goals, which are made up of operations performed within conditions. Reprinted from Kaptelinin & Nardi (2006, Fig. 3.4, p. 64), by courtesy of The MIT Press.

Engeström (1987) extended the concepts of activity and activity contexts into the activity network, shown in Figure 38, by the inclusion of a social dimension. The activity is carried out by a subject within a community. The subject interacts with their community through certain rules of the activity, and the community interacts with the object through the division of labour towards the activity. Engeström (1990) also introduced the concept of upward and downward contextualisation of activity. Upward contextualisation refers to an exploration of the high-level concepts of activity; the motives, values, and context, whereas downward contextualisation refers to an exploration of the low-level concepts; the actions, operations, goals, and conditions. He also introduced the notion that several activity networks could interact with one another, all working towards one shared objective (Engeström, 2001).

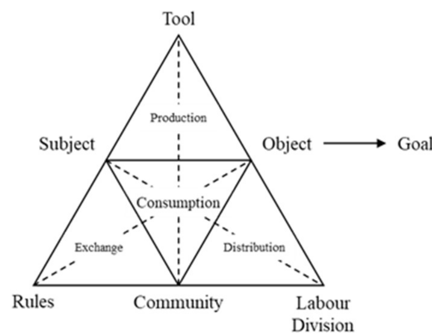


Figure 38. The activity network

The activity network extends the concept of activity contexts with the inclusion of the community, which interacts with the subject through social rules and with the object through the division of labour. Reprinted from Engeström (2014), with permission of Cambridge University Press through PLSclear.

Activity theory is a powerful paradigm for conceptualising and exploring different aspects of serious games for heritage. It has been used effectively for serious games, including the activities of play, learning, and instruction (Marsh, 2010; Carvalho, Bellotti, Berta, *et al.*, 2015) and has also been used to model historical activities and how users create understanding and meaning from them by interacting with museum artefacts through technology (Kaptelinin, 2011). Activity theory, at least as it was presented by Engeström (1987), is able to also take into account the higher level context, motives, and social interactions coupled with both the historical activity and the activity of playing the SGH. Therefore, activity theory is considered a strong basis upon which to base the proposed methodology.

6.5. Presentation of a Methodology for Designing and Analysing Serious Games for Heritage

Keptelinin's (2011) theory proposes that when a museum visitor uses ICT to view a museum artefact, the visitor is the subject of this museum activity context, with the historical artefact as the object and the ICT as the mediating tool. The purpose of this activity is to create a bridging of activity contexts with one of two historical activity contexts; one where the artefact is the object, most commonly the construction of the artefact by a historical actor, and another where the artefact is the mediating tool, most commonly the use of the artefact by a (possibly different) historical actor using the artefact for a particular purpose. This process is shown in Figure 39.a). By learning about and understanding the historical activity context through this bridging process, the visitor thereby gains and internalises "meanings, values, and personal experiences" (Kaptelinin, 2011).

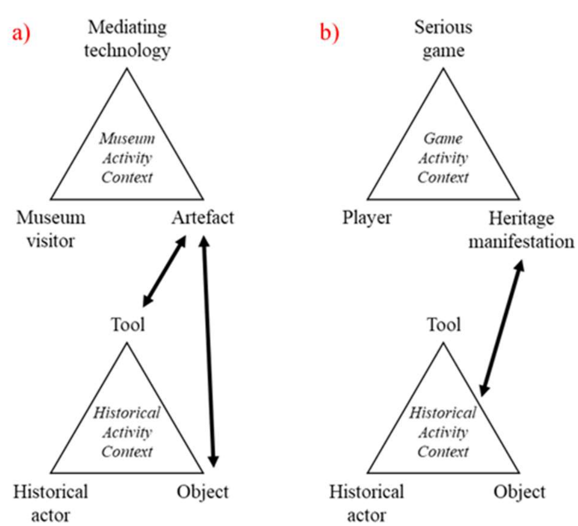


Figure 39. Activity context bridging of ICT in museums and serious games for heritage

a) A museum visitor views an artefact using some mediating technology, thereby bridging with the tool or the object in the historical activity context. Adapted, with permission, from Kaptelinin (2011) © 2011 IEEE; b) a player plays a serious game to observe manifestations of heritage, thereby bridging with any part of the historical activity context. Reprinted from Hanes and Stone (2018).

The proposed methodology suggests that in a similar manner, a player (the subject) interacts with manifestations of historical information (the object) through the serious game (tool), forming the game activity context. One of the purposes of this activity (as well as entertainment) is to create a bridging with the historical activity context. However, due to the expansive possibilities of what heritage and historical information can be manifested through serious games, the manifestation could represent any aspect of the historical activity context, not just the tool or object. These concepts are shown in Figure 39.b). Additionally, the historical activity context could alternatively be an analytical activity, in which historians and archaeologists perform research activities on the given artefacts.

The methodology for designing and analysing serious games for heritage based on activity context bridging comprises three stages, as shown in Figure 40.

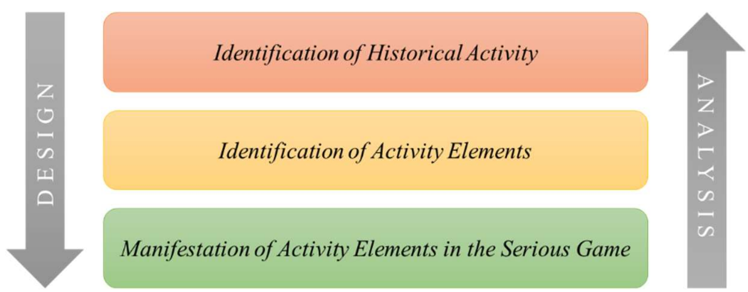


Figure 40. The proposed methodology for designing and analysing serious games for heritage

The proposed methodology has three stages, which are completed in opposite orders, depending on whether it is being used for the design or analysis of serious games for heritage.

When designing serious games for heritage, the three stages should be worked through from top to bottom, starting with the identification of historical activities in the given informational content to be presented through the SGH. Next, each element within each of the historical activities should be identified and described. The third stage is then to explore how each of the elements of historical activity, and their corresponding inter-relationships, can be manifested in the game, such that the player is engaged with the activity through the game mechanics, and activity context bridging is maximised. This process is aided by a set of questions, shown in Table 16, to give insight into how the historical manifestations, and therefore the historical activity, can be integrated into the game mechanics. This should therefore strengthen the link between the historical and gaming activity contexts, and in doing so also improve the meaningful integration of play and learning. The model of historical content in video games, presented in Chapter 3, can be used to help enumerate and define the characteristics of the historical manifestation and its link to the learning outcomes.

When analysing serious games for heritage, the steps are followed bottom to top, starting with the identification and description of the historical content in the SGH, utilising the model of historical content presented in Chapter 3. Next, the activity elements that are represented by the historical content should be identified, and the extent to which they are integrated with the game mechanics should also be evaluated. Finally, the historical activities comprising these activity elements should be identified, drawing attention to any activity elements that are not manifested in the SGH.

Activity Element	Relationship to the Activity Context	Serious Game Manifestation Questions
Activity context	The historical activity in question, being carried out in a given time and place	• Can the player perform this activity? • Is this activity performed by non-player actors? • How is progress in this activity manifested in the game? • How is a successful/unsuccessful outcome manifested in the game? What happens? • How does this activity relate to other historical activities?
Subject	The actor who carries out the activity	• Can the player assume the role of the subject? • How can the player interact with the subject? • How is the subject manifested in the game? • Is affective tone utilised in the manifestation to create empathy with the subject?
Object	The focus of the activity	• How can the player interact with the object? • How is the object manifested in the game?
Tools	The (tangible and intangible) tools used to carry out the activity	• How can the player interact with the tools? • How do the tools affect the performance of the activity? • How are the tools manifested in the game?
Motives	The motives and values that drive the actors to carry out the activity	• How do the motives affect the performance of the activity? • How are the motives manifested in the game? • Is affective tone utilised in the manifestation to create empathy with the motives?
Actions & Goals	The actions and their respective goals that make up the activity	• How do the actions of the activity relate to the actions undertaken by the player? • How does the completion of the actions affect the performance of the activity? • How are the actions manifested in the game? • How are the goals manifested in the game?
Operations & Condition	The operations and their respective conditions that make up each action and goal	• How do the operations of the activity relate to the operations undertaken by the player? • How does the completion of the operations affect the performance of the related action? • How are the operations manifested in the game? • How are the conditions manifested in the game?
Community	The greater community which the subject carries out the activity within	• How is the community manifested in the game?
Rules	Social rules that connect the subject to the community	• How do the rules affect the performance of the activity? • How are the rules manifested in the game?
Labour Division	Systems that distribute the activity amongst the community	• How do the systems of labour division affect the performance of the activity? • Is labour division controlled by the player? • How is labour division manifested in the game?

Table 16. The proposed methodology for designing and analysing serious games for heritage

The manifestation of elements of historical activity in serious games for heritage is aided through a set of questions. These questions give insight into how the elements of activity can be manifested, such that they are integrated into the game mechanics in a way that helps to support player meaning-making. Reprinted from Hanes and Stone (2018).

6.6. Applying the Methodology to Design and Evaluation Processes

In this section, suggestions will be made for how the presented methodology can be utilised alongside other conceptual frameworks for serious game design and evaluation, by proposing how the methodology could be integrated into one such framework; the 13-step serious game design process presented by Tang & Hanneghan (2014), while also incorporating aspects of the SGH evaluation processes suggested by Birchall *et al.* (2012). The framework of Tang & Hanneghan (2014) was chosen for this process because it is one of few SG frameworks that considers the whole serious game development process, built on methods and best practices established and refined by the commercial video game industry. The framework of Birchall *et al.* (2012) was chosen because it presents a clear review of the state-of-the-art in evaluation methods for serious games for heritage and when and how to use them.

The following steps are taken from Tang & Hanneghan (2014), and detail how the proposed methodology might be applied to this framework:

Step 3 - Identify Learning Activities for Learning Objectives – Identifying and designing the learning activities can be assisted using the presented methodology to identify and explore the historical activities present within the historical informational content for the learning objectives and how they can be represented within the serious game.

Step 6 - Design Game Mechanics for Learning Activities – The presented methodology can be used to assist in the design of the core game mechanics by considering the historical activities and how each element of those activities can be manifested in the game mechanics, such that activity context bridging is maximised.

Step 7 - Design Game Components and Associated Behaviours – The presented methodology with the model of historical content can be used to assist in the design of each game component and how the informational content and each component of the historical activities are manifested in the serious game, and the systems and behaviours associated with them.

Step 10 - Evaluate Prototype Against Learning Objective – As each level and segment of the game is prototyped, formative evaluation should take place, as detailed by Birchall *et al.* (2012), whereby the prototypes are tested with members of the target audience using methods such as observations and questionnaires. During this evaluation, attention should be paid to the extent to which the gameplay and narrative of the serious game create cognitive empathy (Kidd 2015) towards the historical actors and the activities they partake in.

Step 13 - Quality Assurance (QA) Test on Educational Game – Once the serious game is fully developed it can be play-tested in its entirety. As in the evaluation of the prototypes for each level, methods such as observations, questionnaires, and interviews can be used to ascertain the extent to which the holistic game experience can create a sense of cognitive empathy and successfully bridge the manifestations with the historical activity context.

Finally, as recommended by Birchall *et al.* (2012), post-launch summative evaluation can be carried out with the use of player statistics, questionnaires, interviews, and perhaps most promisingly, game analytics. As was discussed in Section 0, game analytics form a promising and insightful future direction for serious games (Freire *et al.*, 2016). Future research in this approach should therefore focus on how game learning analytics can be best used and exploited for evaluating the extent to which serious games for heritage are able to effectively achieve bridging of activity contexts.

6.7. Strengths and Limitations of the Proposed Methodology

The first strength of the proposed methodology for designing and evaluating serious games for heritage is its use of activity theory, which has already been shown as an effective framework for modelling serious games (Marsh, 2010; Carvalho, Bellotti, Berta, *et al.*, 2015). One could also argue that by considering the greater social context and relationships of serious games, by using Engeström's (1987) activity networks, SGs will be more able to reach Egenfeldt-Nielsen's (2007) proposed "third generation" of educational video games, which focus on the socio-cultural context of the SG experience. In the presented methodology, activity theory is simply extended to include the history and heritage domain, for which it is already highly suited. An anticipated advantage of this is that it should act as a common "vocabulary" for game design, history, and pedagogy experts, improving communication between different subject experts involved in creating effective SGsH.

Furthermore, it is anticipated that activity theory should be an effective paradigm for manifesting and exploring intangible heritage material, due to its focus on human activity and its socio-cultural relationships, rather than physical artefacts (UNESCO, 2003). This is an important factor due to the wealth of digital heritage and research directed at intangible heritage (e.g. Linaza, Moran and O'Connor, 2013; Aristidou *et al.*, 2017; Doulamis *et al.*, 2017).

The next advantage of the proposed methodology, which will be confirmed when applying the methodology to the SGH design process in Chapter 7, is its usefulness at the concept generation phase of SGH design. This is due to its use of simple open-ended questions, shown in Table 16, to suggest how content might be manifested in the SGH and stimulate the idea generation process.

Finally, as already mentioned, the methodology should help achieve better integration of play and learning in serious games for heritage, as well as supporting player meaning-making, through the bridging of activity contexts. This is achieved by manifesting heritage and historical content in the SGH, such that the actions of the player, manifested through the game mechanics, have real historical analogues and are meaningful in the given historical context.

The first limitation of the presented methodology is that it pushes SGH design in the direction of creating new and innovative game mechanics and designs based off the historical content, rather than simply applying the historical content to existing and proven game designs. This approach, termed “intrinsic” SGH design by Schaller (2014), may lead to more interesting and effective SGsH with better integration of play and learning, however it also requires more design resources and entails more risk, for there is a greater chance that the resulting game is not fun or engaging for the target user group.

Next, the proposed methodology is not prescriptive, and cannot generate serious games designs, mechanics, or systems from given informational content. The SGH design process still involves a great amount of challenge and requires imagination, creativity, and close collaboration between game, content, and pedagogy experts. However, such a prescriptive game generation procedure would likely not be desirable anyway, and the proposed methodology attempts to make the design processes more effective, by stimulating ideas and suggestions for the manifestation of historical content within the game mechanics and systems.

The last limitation of the proposed methodology is that its use of activity theory creates a strong human-centric focus in the resulting serious games for heritage, since the theory focuses on the nature and context of human activity. However, this may be somewhat less appropriate for natural heritage informational content, depending upon the aims and focus of the SGH project. However, the approach would still be effective for manifesting and exploring human interactions with natural landscapes and environments.

6.8. Conclusions

6.8.1. Chapter Conclusions

This chapter partly addressed the fourth and final secondary research question. A discussion was held to address how the design of serious games for heritage might be applied specifically to the field of Assyriology and ancient Mesopotamian history, based on the interview with the field expert in Section 1.6. This included how SGH design could be applied to artefacts and knowledge within Assyriology, the presentation of modern archaeological activities, as well as overcoming the challenges and exploiting the opportunities specific to Assyriology. The overall conclusion was that the presentation of historical activities, as well as modern analytical activities, is highly important to designing serious games for Assyriology, and will likely be to other historical fields too.

A methodology was then presented for the design and evaluation of serious games for heritage, based on activity theory. The aims and approach of the methodology were first discussed, which use an SGH to create activity context bridging between the play and learning activities contained in the SGH and the historical activities or modern analytical activities in the learning outcomes, to foster better understanding, empathy, and meaning-making for the user. The methodology utilises three simple steps and a set of implementation-focused questions to help direct and stimulate ideas of how the given heritage and historical information can be manifested in the serious game using game mechanics and systems that support player meaning-making. An approach for applying the methodology to the state-of-the-art in SGH design and evaluation frameworks was proposed, and the strengths and limitations of the methodology were also discussed.

Designers of serious games for Assyriology are now equipped with better insights and methodologies for applying serious games for heritage to the particular characteristics, opportunities, and challenges of the field. Furthermore, many of the points raised and the approaches developed will likely be highly transferable to designing and evaluating serious games for other fields of cultural heritage.

6.8.2. Applications to the Thesis

In Chapter 7, the methodology proposed here will be applied to the analysis and redesign of a serious game for Assyriology to ascertain its effectiveness as a usable and useful methodology for the processes of designing, developing, and analysing serious games for heritage.

Chapter 7 A Case-Study for Analysing and Designing Serious Games for Assyriology

7.1. Introduction

This chapter will fully address the fourth secondary research question, defined in Section 2.9.2, by presenting a case-study for the analysis and design of a serious game for Assyriology. This case-study will implement the methodology presented in Chapter 6, thereby evaluating its efficacy and value. It is proposed that this can best and most feasibly be achieved by taking an existing Assyriology SGH, and analysing it using the proposed methodology, to gain insight into where the game is strong or weak at presenting historical activity, especially through the serious game mechanics. Concepts can then be proposed for how the SGH might be redesigned to improve it in the aspects identified. This approach allows the methodology to be utilised for both analysis and design within a single case-study that is small enough to be completed within the given limitations on time and resources.

The proposed target of this case-study is the British Museum's (2006b) Mesopotamia website, which aims to educate upper Key Stage 2 schoolchildren on various topics in ancient Mesopotamian history. The website contains a wealth of information and resources, split across ten chapters, each of which contains a serious game that aims to summarise and reinforce the material learned throughout that chapter. Additionally, there are also many resources for teachers and educators providing all the informational content contained within each chapter. This Mesopotamia website is an ideal target for the case-study for three reasons; each chapter is based on a well-defined set of learning objectives and informational content, each serious game is focused upon the content explored within that chapter, and because each serious game is small and limited in scope, with simple but engaging gameplay.

This chapter will begin with the selection and justifications of the base SGH for the case-study, as well as the analysis of this base game using the methodology presented in Chapter 6. It will then detail the redesign of the game, also using the methodology. Finally, the development of a working prototype based on these designs will be developed, which will be evaluated through a user-test. As was proposed in Chapter 6, the methodology can be integrated into existing SG design frameworks, such as that presented by Tang and Hanneghan (2014). The approach taken in this chapter will therefore follow the relevant steps of that framework, as follows:

Step 3: Identify Learning Activities for Learning Objectives – the relevant information contained within the teachers' resources will be explored using the proposed methodology, and the learning activities of the game will be expanded to achieve a deeper exploration of the identified historical activities.

Step 6: Design Game Mechanics for Learning Activities, Step 7: Design Game Components and Associated Behaviours – an expanded set of game mechanics, components, and behaviours will be designed, based on the expanded learning activities. This will be achieved through a process of design conceptualisation and brainstorming, in collaboration with an Assyriology field expert, followed by a stage of concept generation, refinement, and selection. Finally, there will be a stage of final design, which will be guided by the proposed methodology, to ensure that the game systems are well-integrated into the context of the learning content.

Step 9: Prototyping – the development of a playable prototype SGH will then be described.

Step 10: Evaluate Prototype Against Learning Objectives – finally, the prototype will undergo a stage of user testing to ascertain its playability, user engagement, and its effectiveness at achieving its learning objectives. The results of this user-test will be presented and discussed.

Although limitations on the time and resources available within the project do not allow the development process to extend any further, a discussion will be held on what the next steps of the development process would be and how the work detailed in this chapter would inform and guide those next steps. Finally, an overall evaluation of the efficacy of the presented methodology for the analysis and design of serious games for heritage will be given.

7.2. Analysing Serious Games for Assyriology

7.2.1. Base Serious Game

The SGH selected as the base game for the analysis and redesign case-study is contained within the "Ziggurats" chapter of the Mesopotamia website, called "Building a Ziggurat" (The British Museum, 2006a). The learning objectives of the game are to teach players about the different tasks involved in the construction of a ziggurat, to teach players about the logistical coordination necessary to align these tasks together, and finally to teach players the motives behind the construction of ziggurats.

In the game, the player assumes the role of the ruler of a Sumerian city who has been tasked with constructing a ziggurat for the king, to please the gods. Screen captures from the game can be seen in Figure 41. The first stage of the game is a simple textual introduction which explains the role the user must assume and the game systems. In the next stage the player is given a number of workers, whom they can assign to 4 different tasks – digging clay, making bricks, carrying bricks, and laying bricks. These 4 tasks move resources between 4 different stockpiles, resulting in the construction of the ziggurat. The aim of the game is to assign different numbers of workers to each task such that the ziggurat is completed, which is performed in 3 separate stages. No time or score metrics are recorded, and once the third stage of ziggurat construction is complete, the player is presented with a congratulatory message.

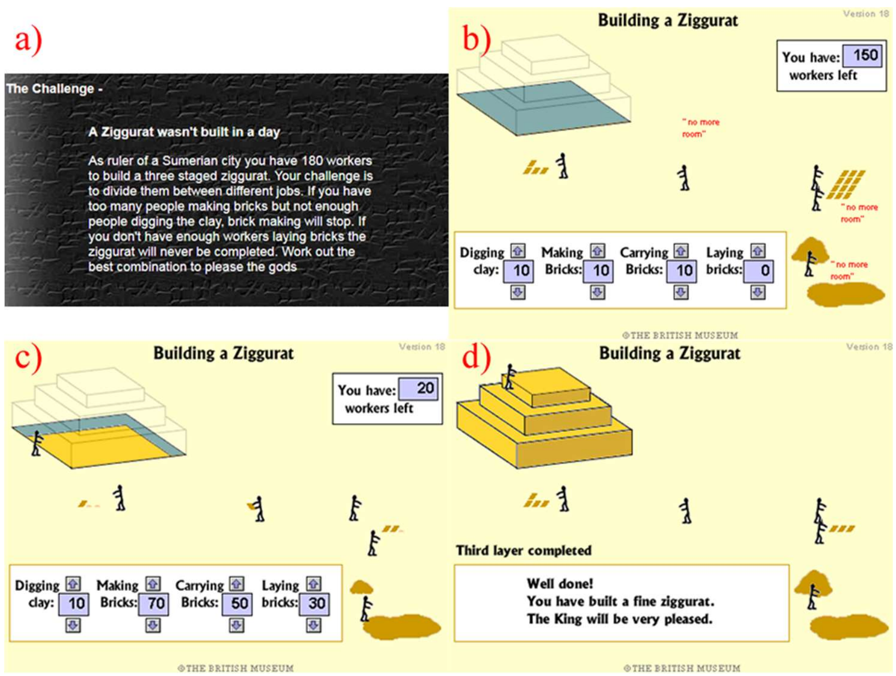


Figure 41. Screenshots from "Building a Ziggurat"

a) The introductory text; b) the gameplay showing feedback messages; c) the gameplay showing partial completion of the ziggurat; d) the game win state. Adapted from The British Museum (2006a) © The British Museum.

The target users of the game are the same as the rest of the Mesopotamia website, schoolchildren in upper Key Stage 2 (ages 7-11), and the target context of use is self-guided use through an internet browser. The player will play the serious game at the end of the ziggurats chapter, as an opportunity to learn about the topic in an experiential manner and to reflect upon what they have learned in the rest of the chapter.

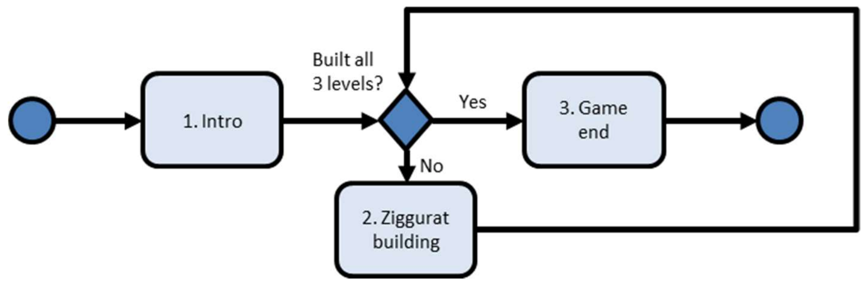
An analysis of each of the 10 serious games on the Mesopotamia website was performed using the proposed SGH methodology, as well as state-of-the-art serious game conceptual frameworks. The analysis for Building a Ziggurat is shown in the following sections. This serious game was chosen as the target for the present case-study because, as will be seen, it contained engaging and fun gameplay, while also lacking in the presentation and exploration of historical activity.

7.2.2. Analysis of the Base Game

This section details the analysis of the chosen base game, Building a Ziggurat, first using two serious game conceptual frameworks; Carvalho *et al.*'s (2015) Activity Theory-based Model of Serious Games (ATMSG) and Hall *et al.*'s (2014) methodology for embedding instructional learning objectives in the serious game core mechanics. As was discussed in Chapter 2, these frameworks afford insight into the gaming, learning, and instructional activities of the serious game, and how they bring about effective learning of the instructional content and are considered the current state-of-the-art in serious game conceptual frameworks.

a) ATMSG Analysis

The ATMSG (Carvalho, Bellotti, Berta, *et al.*, 2015) analysis of the base SGH, Building a Ziggurat, is shown in Table 17, where the game is broken down into a logical flow of "game sequence nodes". For each node, the gaming, learning, and instructional activities are described in terms of their actions, tools, and goals. The second stage of the analysis is shown in Table 18, where a more detailed description of each activity is given for each of the game sequence nodes.



		1. Intro	2. Ziggurat building	3. Game end
Gaming	*Actions*	Read	Manage resources	–
	Tools	Tutorial; Tips	Levels; Zero-sum; Progress bars	–
	Goals	Discover goal; Learn to use interface	Maximize performance	–
Learning	*Actions*	Read	Modify; Experiment	Review
	Tools	Rules; Tasks	Graphics; Challenge	Graphics; Information
	Goals	Remembering	Applying	Understanding
(Intrinsic) Instruction	*Actions*	Present material	Present problem; Repetition	Reward good performance
	Tools	Help text	Challenge	Performance measure
	Goals	Gain attention; Attention	Present the stimulus; Elicit performance; Relevance; Confidence	Assess performance

Table 17. ATMSG activity analysis of Building a Ziggurat

The first stage of the ATMSG framework (Carvalho, Bellotti, Berta, et al., 2015) applied to the base SGH, Building a Ziggurat (The British Museum, 2006a). Here, the game is divided into three game sequence nodes, and each is described in terms of the gaming, learning, and instructional activities involved.

The ATMSG analysis shows how the player is introduced to the serious game tasks, how the game teaches the relevant information needed to complete the objectives, how players receive positive reward and feedback upon successfully completing those objectives. It also shows how the serious game acts as an instructional tool, gaining the player's attention, presenting a stimulus for performance, and assessing that performance.

Game Sequence Node	Gaming	Learning	(Intrinsic) Instruction
1. Intro	The player must read the tutorial text to discover the goal of the game and how to use the interface. The tutorial also gives some tips for how to play effectively.	The player must read the game instructions to ascertain the task they are trying to complete. Here they also learn motive behind their task, as well as some of the sub-tasks involved in the construction process.	The game presents a textual tutorial to gain the attention of the player and inform them of the context of the task they are to perform. The task teaches the player the goal they must complete and some tips of how to achieve it.
2. Ziggurat building	The player must allocate 180 workers to 4 different tasks which use/generate different resources. The quantity of each resource is visible, and the building progress of the ziggurat acts as a progress bar that the player is trying to complete. The player is trying to complete the ziggurat construction, although no performance metrics are given. The level is repeated 3 times.	The player can modify the number of workers assigned to each stage of the construction process chain to experiment with different balances to optimise the ziggurat construction. They must apply what they have learned in the tutorial.	The game challenges the player to apply what they have learned about ziggurat construction by balancing the numbers of workers assigned to each stage of the construction process, to successfully build the ziggurat. The building is completed in 3 separate stages.
3. Game end	–	The player is presented with a graphic of the completed ziggurat and a short text reviewing their performance, informing them that a fine ziggurat has been completed, and that the king will be pleased. The player can then understand the positive impact of their actions.	The game assesses the player's performance, always giving positive feedback. The player is provided with a reward of the graphic of the completed ziggurat.

Table 18. ATMSG activity description of Building a Ziggurat

The second stage of the ATMSG framework (Carvalho, Bellotti, Berta, et al., 2015) applied to the base SGH, Building a Ziggurat (The British Museum, 2006a). Here, the implementation of each game sequence node is described, for the associated gaming, learning, and instructional activities.

Successful engagement is attained by providing the player with detailed and constant feedback on the game states. The gameplay creates a fast and repeating game loop, where the player must be constantly looking over the levels of each stockpile and re-assigning workers between the different tasks to improve the optimisation of the construction supply chain. By using an appropriate level of complexity, the game can create an experience in the corridor of flow, not too complex and difficult to be stressful and overbearing, and not too simple to be boring or under-demanding. The result is a gameplay experience that is engaging and fun, albeit for a limited play session.

b) Hall *et al.* Model Analysis

ATMSG is less effective at analysing how the player may or may not learn the intended informational content through their interactions with the serious game mechanics. Therefore the model presented by Hall *et al.* (2014) is also employed, as shown in Table 19, which aims to analyse how the core serious game mechanics may or may not lead to effective learning of the instructional material.

By examining the game core mechanics loop in this analysis, it is possible to observe the extent to which the mechanics of the game are effective at presenting and teaching the informational content. For the first learning objective, recalling the processes involved in the construction of a ziggurat, the processes themselves are only shown with a text description and simple 2D graphics and animations, and successful recognition of the processes is not required by the mechanics to be successful. For this reason, the goal is considered only partly achieved. The second learning objective, understanding the level of organisation required in ziggurat construction is achieved. This is because the game's mechanics of assigning and de-assigning workers to each process directly shows one of the challenges of ziggurat construction and the player must use a level of organisation to overcome this challenge. Finally, the third learning objective, understanding the motives behind ziggurat construction, is barely achieved at all, because it is only briefly mentioned in short texts at the beginning and end of the game, but does not appear in the mechanics.

Category	Question	Description
Goal	G1: What performance should I be able to achieve?	Recall the processes involved in building a ziggurat, understand the levels of organisation required, and the motives for building ziggurats.
Choice	CH1: What can I do and what are my alternatives?	The player can choose which tasks to assign different numbers of workers to.
	CH2: How is the possibility of choice conveyed?	This choice is conveyed through the UI, where there are numbers of workers assigned to each task, next to up and down arrows, which afford the user to modify each of those numbers.
Actions	A1: What series of actions (verbs) will indicate I am making a choice?	The player assigns or un-assigns workers to each of the tasks, by clicking on the relevant buttons in the UI.
Rules	R1: (speed) How quickly do I need to make my choice and perform the actions to achieve my desired goal?	No speed- or time-related rules or conditions are implemented.
	R2: (Accuracy) To what degree or level or precision do I have to demonstrate to achieve my desired goal?	There is a predefined set of optimum worker numbers to apply to the tasks. The closer the user's assignment is to this optimum, the better their performance will be and the faster the ziggurat will be built.
	R3: (Quality) What standards/criteria do I have to meet whilst I perform the actions to achieve my desired goal?	No quality rules or conditions are implemented.
	R4: (Conditions) In what conditions will my performance occur?	All the tasks, and their associated performance speeds, are constant and do not change. The total number of workers is also constant.
	R5: (Constraints) What can/cannot I use whilst making a choice and performing the actions?	Once all workers are assigned, more cannot be assigned unless some are un-assigned from a different task.
Feedback	F1: What is the result/new state of the environment once the choice and actions are made?	Once workers are assigned, the task they were assigned to will progress faster, which will lead to the ziggurat being completed at a faster or slower rate.
	F2: How do I know I made the correct/incorrect choice?	The user knows whether their assignments were good or bad, based on how the stockpile levels change after the assignment, and how quickly the ziggurat is built.
	F3: How will it affect future choices?	Unlimited further re-assignments can be made to the tasks, which will further affect the different stockpile levels and the speed at which the ziggurat is built.
Goal	G1: What performance should I be able to achieve?	Recalling the processes involved in building a ziggurat is partly achieved, understanding the levels of organisation required is achieved, but understanding the motives for building ziggurats is not achieved.

Table 19. Analysis of learning through serious game mechanics for Building a Ziggurat

The model presented by Hall et al. (2014) was applied to the SGH Building a Ziggurat (The British Museum, 2006a) to analyse instruction embedded in the serious game mechanics.

7.2.3. Analysis of Exploration of Historical Activity

The methodology for analysing serious games for heritage, presented in Chapter 6, can be utilised to evaluate the extent to which Building a Ziggurat explores historical activity and achieves bridging of activity contexts. The results of this analysis process are shown in Table 20.

Activity Element Type	Activity Element Description	Serious Game Implementation
Activity	Building of a ziggurat	The player performs this activity by managing the labour division of the actions (digging clay, making bricks, moving bricks, and laying bricks). One tool is the plan for the construction, which is shown through the "ghost" ziggurat graphics always present while the ziggurat is being built. Progress is shown by the graphics of the ziggurat which show increasing levels of completion. Upon completion of the activity, the game is won. No community relation is shown. No rules of the activity are shown. Context is shown through text at the beginning, describing the situation of a Sumerian city where a ziggurat is being built. Meaning and motive of the activity is briefly described through text, that the gods and the king are pleased by completion of the activity.
Object	Ziggurat	The player completes the building of the ziggurat. It is shown through a simplified graphical representation at different levels of completion.
Subject	Ruler of the city	The player assumes the role of this character. They are briefly mentioned in the introductory text.
Labour Division	Ziggurat workers	The player assigns the workers to each process. They are shown as simplified "stick-men" in animations for each of the processes.
Motive	The King	Upon completion of the ziggurat, the player is informed through text that the king will be very pleased.
Motive	The Gods	In the introductory information, the player is informed through text that building the ziggurat will please the gods.

Table 20. Activity analysis of Building a Ziggurat

An analysis of Building a Ziggurat (The British Museum, 2006a) and its presentation and exploration of historical activity, using the methodology presented in Chapter 6.

The analysis showed that the only historical activity the game focuses on is the building of a ziggurat. There is good downward contextualisation of this activity, as the player can see the different actions that make up the activity and because the game's mechanics focus on managing the labour division aspect of the activity. However, the upward contextualisation is very poor. There is next to no mention of the setting or context in which the activity is taking place, or the motives behind the activity. The only mention of these aspects is through very brief elements of text at the beginning and end of the game, but not through the mechanics. The building of the ziggurat is the only activity explored; no other activities containing the ziggurat. Therefore, overall, the activity context bridging can be said to be fair, but not good. Accordingly, the serious game is not very effective at achieving a meaningful integration of play and learning.

7.3. Designing Serious Games for Assyriology

7.3.1. Enumeration of Historical Instructional Information

As described in Section 7.1, the first step of the Assyriology serious game redesign process was to enumerate and analyse the historical instructional information to be presented through the game, with the aim of expanding the learning activities of the SGH to better facilitate activity context bridging. This step corresponds to step 3 of the methodology presented by Tang and Hanneghan (2014); "Identify Learning Activities for Learning Objectives". The learning objectives were not altered and were the same as those stated in Section 7.2.1.

Within the teachers' resources section of the Mesopotamia website (The British Museum, 2006b), there are a number of resource pages, each giving detailed background information on a particular topic. First, the text from the resource pages relating to the ziggurat serious game was examined and the historical information contained within was enumerated. An example of this information enumeration is shown in Table 21.

Resource Page Text	Information Type	Information Description
Ziggurat is an anglicized form of the Akkadian word ziqqurratum, the name given to the solid stepped towers of mud brick. It derives from the verb zaqaru, ‘to be high'.	Property	"Ziggurat" derives from the Akkadian "ziqquratum"
	Artefact	Ziggurats are solid stepped mud brick towers
	Property	"Ziqquratum" derives from "zaqaru", 'to be high'
The ziggurat was part of the religious architecture found at the centre of Mesopotamian settlements and was probably a feature of most cities after c.2000 B.C.	Property	Ziggurats are religious buildings
	Collection of artefacts	Buildings within a Mesopotamian city, with a ziggurat in the middle
	Collection of artefacts	Mesopotamian cities after 2000 B.C. with a ziggurat
Millions of sun-dried mud bricks were used in their construction. Layers of bricks were often separated by layers of reeds, perhaps helping to spread the load or allow drainage.	Activity	Building of ziggurats with many mud bricks
	Activity	Layering of bricks and reeds
	Collection of artefacts	Layers of the ziggurat
Baked bricks and bitumen were used to protect the exterior from rain and wind.	Activity	Applying of baked bricks and bitumen to the ziggurat exterior
	Collection of actions	Stages of ziggurat building, interior then exterior

Table 21. Example of resource page text enumeration

An example of how the text from the resource pages on the Mesopotamia website was coded and enumerated. The text shown is taken from the ziggurat resource page[23].

7.3.2. Analysis and Exploration of Historical Activity

Once the resource pages relating to the Building a Ziggurat SGH had been enumerated, the historical activities and their constituent elements could then be defined and described, corresponding to the first two stages of the methodology proposed in Chapter 6. An example of such a definition and description is shown in Table 22. This work could then be used to perform the next stage, where serious game mechanics and components would be proposed and designed to support the expanded learning activities.

[23] http://www.mesopotamia.co.uk/staff/resources/background/bg22/home.html

Activity Element		Constituent Elements	
Type	***Description***	***Type***	***Description***
Activity	Constructing the ziggurat at Ur	Setting	Ur, 2100 BC
		Subject	Ur-Nammu
		Tool	Mesopotamian measurement system
		Tool	Mathematics
		Tool	Construction plans
		Object	Ur-Nammu's ziggurat at Ur
		Labour Division	Workers assigned to different actions
		Context	Ziggurats also later constructed at Uruk, Eridu, and Nippur
		Motive	To show Ur-Nammu's power
		Motive	For the God Nanna
		Action	Making mud-bricks (operations are pressing mud into moulds, drying them in the sun, turning them out)
		Action	Laying mud-bricks
		Action	Laying layers of reeds
		Action	Making baked bricks (operations are pressing clay into moulds, turning them out, stamping some of them with the name of Ur-Nammu, stacking them, covering them with a dome of mud, burning twigs in the dome, and removing the bricks)
		Action	Laying baked bricks
		Action	Applying bitumen
Object	Ur-Nammu's ziggurat at Ur	Property	Dedicated to the moon god Nanna
		Property	Called "Etemennigur" or "House whose foundation creates terror"
		Property	Different components – buttresses, staircases, gate, weeper holes, drains, terraces, temple
		Property	Had a mud-brick core with a baked brick outer
		Property	First storey contained 720,000 baked bricks
		Property	First storey contained nearly 7,000,000 mud-bricks
		Property	Had a layer of crossed reeds for every ~6 layers of mud-bricks

Table 22. Example of ziggurat activity definitions and descriptions

An example of how the activities, and their constituent elements, were defined and described for the enumerated historical information from the resource pages.

7.3.3. Serious Game Brainstorming

As described in Section 7.1, the second step of the Assyriology serious game redesign process was to design serious game mechanics and components for the newly expanded learning activities. This corresponded to the final stage of the methodology for designing serious games for heritage, proposed in Chapter 6, whereby the defined activities and their constituent elements are manifested in the SGH, according to the model presented in Chapter 3. This was achieved using processes of brainstorming and concept development, which are recommended for the development of commercial games by Fullerton (2014, chap. 6). These processes were chosen due to their extensive validation within the video game industry, and because the model of Tang and Hanneghan (2014) simply does not offer enough detail for how to carry out these steps.

This first process, serious game brainstorming, consists of freely imagining and creating different ideas for how the activity elements defined in the previous section could be manifested in the serious game, with an expanded set of learning activities, to achieve the originally stated learning objectives. These ideas were generated and added to a single mind map diagram (Fullerton, 2014, chap. 6). This brainstorming process was carried out with the Assyriology field expert introduced in Section 1.6, to ensure the robustness of the ideas put forward, in terms of their informational content. The resulting mind map diagram was completed on paper and is shown in Figure 42.

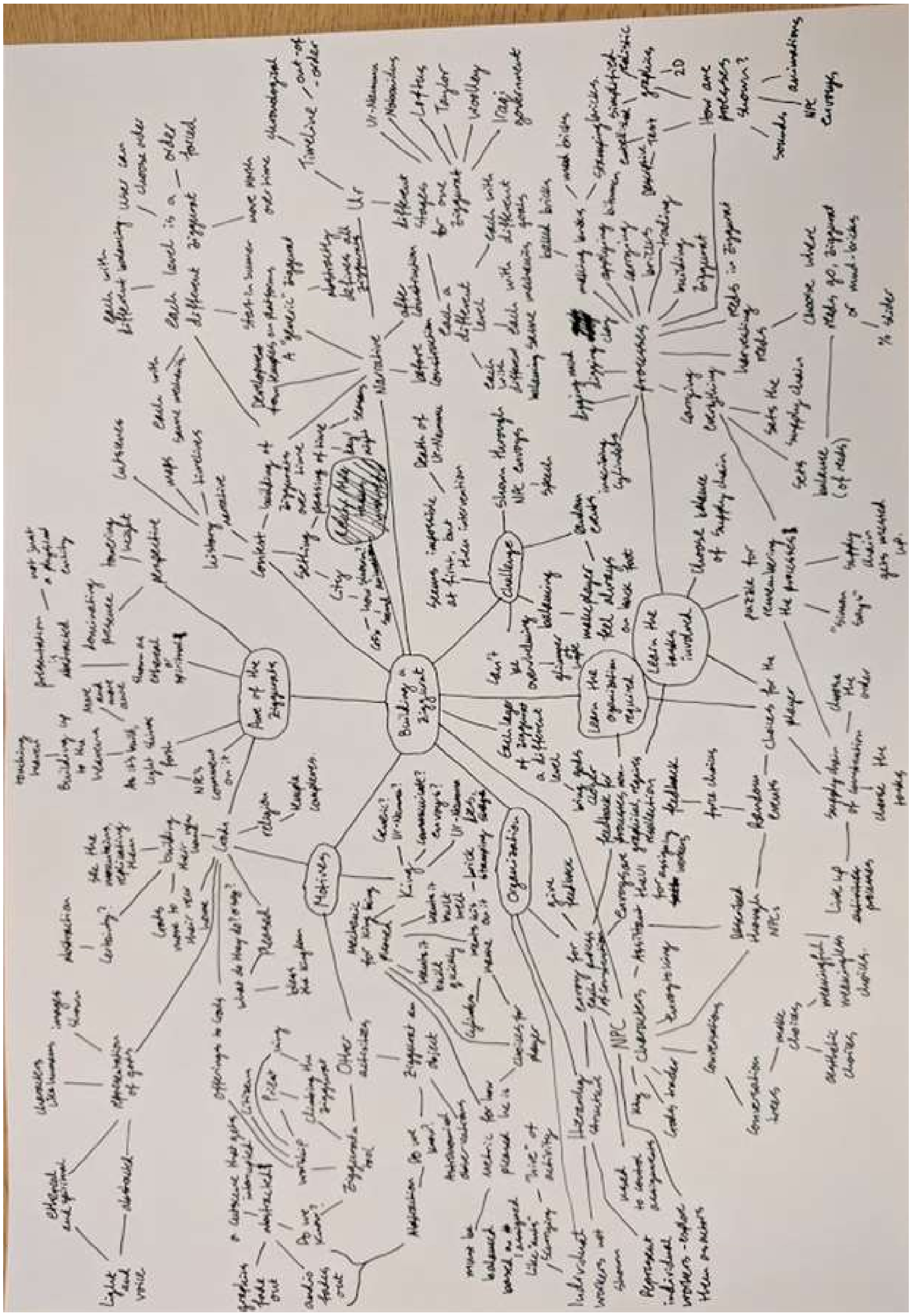


Figure 42. Mind map diagram produced through brainstorming process for Assyriology serious game design

7.3.4. Concept Development, Storyboarding, and Selection

As Fullerton (2014) recommends for commercial games, a set of three different serious game design concepts were suggested and refined, based off ideas generated and explored during the brainstorming process, which could achieve the stated learning objectives and maximise the bridging of activity contexts. For each concept, the game mechanics and systems, the narrative and characters, and the player interactions and objectives were specified. To also ensure the strength of the concepts from a serious game and pedagogical perspective, the concepts were further developed and refined with the assistance of the project supervisor, drawing upon his experience and knowledge in the serious games domain.

For each serious game concept, a storyboard was then produced, made up of a series of images which attempt to represent the approximate appearance of each section of the concept, to help demonstrate the gameplay interactions. Next, the analysis that was performed for the original base Assyriology serious game in Section 7.2 was repeated for each serious game concept, to ensure that the design would (at least theoretically) improve the achievement of the learning objectives and the bridging of activity contexts. Finally, with the assistance of the project supervisor, the three concepts were each discussed and compared, in terms of their capacity for achieving their objectives, their feasibility to be developed, and their predicted success in terms of creating a fun and engaging gameplay experience. One of the concepts was selected to be taken forward to the prototyping stage, and the expanded learning activities, design, and analysis of this chosen concept will be presented in the following section.

7.3.5. Design of the Serious Game for Assyriology

In the chosen concept, it was decided that the expanded learning activities should involve a deeper exploration of the ziggurat construction activity, especially its upward and downward contextualisation. The concept would include more of the actions, actors, and other constituent elements of the construction activity, and how they combine together to achieve its central aim. It would also include more exploration of the context and motives behind the activity, and why the principal actors are carrying it out.

In the chosen concept, as in the original game, the player assumes the role of the ruler of an unnamed Sumerian city, tasked by the king with building a ziggurat to please the gods. The player must construct the ziggurat by balancing the workers assigned to each of the construction processes, as in the original game, however at random points the player must also take part in different mini-games which relate to different aspects of the ziggurat construction processes. This design approach based on mini-games has also been utilised successfully in other serious games for heritage (e.g. Bellotti *et al.*, 2012; Schaller, 2014; Bossavit *et al.*, 2018; Wang, 2018) and is supported by several theories of learning (Smith and Sanchez, 2010). Some mini-games are designed such that success at the mini-game requires the player to learn and apply the informational content, however for others this is applied to a lesser extent. If the player succeeds at the mini-game, one of the construction processes receives a positive modifier, and if they fail the process receives a negative modifier. There is also a simple character speech system to show speech from different actors, used to introduce the game and each mini-game. This speech system is used to present the motives and reasons behind each actor's decisions and actions. Throughout the entire game, there is a running clock, and the overall aim of the game is for the player to complete the ziggurat in a minimum time. This concept attempts to push the mechanics of the original game towards requiring the player to learn the informational content to be successful at the game. Because of the modular mini-game structure of this concept, it is easier to combine somewhat different pieces of informational content together, which would be harder to marry together in a single set of mechanics. The following sections detail the design of each mini-game and the analysis of activity performed on this chosen serious game concept.

a) Design and Analysis of Mini-Games

Ten separate mini-games were designed for the chosen game concept, and a description and brief analysis of each mini-game, relating to the embedding of instruction in the mini-game mechanics and the exploration of historical activity, is shown in Table 23.

One of the mini-games that is worth describing further is the first listed in Table 23; "Questions with the King". In this mini-game, the player must answer three randomly selected multiple-choice questions. Some of these questions present new information and expect the player to interpret it to answer the question correctly, whereas some questions test learning of information presented in other parts of the game. All the questions explore different aspects of the ziggurat-building activity at the centre of the game, through both upward and downward contextualisation, including the setting and motives of the activity, as well as the actions and tasks that comprise it. There is even some minor exploration of other activities involving the ziggurat, such as its use in religious ceremonies. In this way, this mini-game is very important for effectively binding the whole game together into a single exploration of the ziggurat construction activity. If players get questions wrong, they will receive feedback on the incorrect answer and be able to retry those questions the next time they attempt the mini-game.

Mini-Game Name	Associated Character	Learning Objectives	Gameplay Mechanics and Objectives	Embedding of Instruction in the Mechanics	Exploration of Historical Activity
Questions with the King	The King	To learn about all the different aspects of ziggurat construction covered in the game.	The player is asked three random questions about different aspects of the ziggurat building activity.	The player is given a set of answers to choose from, and feedback is given when the player selects an answer. Therefore, instruction is well-embedded.	The questions relate to all aspects of the ziggurat construction activity covered by the rest of the game. Therefore, exploration of activity is good.
Making Mud Bricks	Chief Brick Maker	To learn the operations involved in making mud-bricks and their order.	The character explains the order of operations for making mud bricks. The player must then repeat this order for several bricks by clicking the correct buttons.	There are several buttons, and the player must press them in the correct order, based on their learned knowledge of the order of operations for making mud bricks. Therefore, instruction is well-embedded.	The motivations behind the making of mud bricks are well-described. Therefore, exploration of activity is good.
Building the Ziggurat	Ziggurat Architect	To learn the operations involved in constructing a ziggurat and their order.	The character explains the order of operations for building the ziggurat. The player must then repeat this order by clicking the correct buttons.	There are several buttons, and the player must press them in the correct order, based on their learned knowledge of the order of operations for building the ziggurat. Therefore, instruction is well-embedded.	The motivations behind the building of the ziggurat are related to the overall motivations of the game. Therefore, exploration of activity is good.
Importing Reeds	Chief Importer	To learn about the geographical makeup of the Neo-Sumerian Empire, and how reeds could be grown and transported for use in the construction of ziggurats. Also, how cuneiform tablets could be used to help trace the movement of goods through the trade network.	The player is informed that a boat of reeds is somewhere in the harbour amongst other boats. They are told which city the boat comes from, and each city has a cuneiform symbol, shown on a map. By viewing the cuneiform symbol for each boat, the player must select the correct boat.	The player is presented with several boats they can mark as the one containing the reeds. They must match the cuneiform symbols of the cities to identify the correct boat. Therefore, instruction is relatively well-embedded.	The motivations behind the importing of reeds are well-described. Therefore, exploration of activity is good.
Stamping Clay Bricks	Chief Brick Maker, the King	To learn that some clay bricks were stamped with the King's name, and why	The characters explain the motivation behind the stamping. Then, the player must stamp several bricks, by clicking on them, before a timer expires.	The player must click bricks as quickly as possible. Therefore, instruction is not well-embedded.	The motivations behind the player's stamping of bricks are well-described. Therefore, exploration of activity is good.
Digging Mud and Clay	Chief Miner	To learn how mud and clay could be dug out of the ground for use in the construction of ziggurats.	The player must direct workers in the mine to either dig up mud or clay and send it to the city, according to what the city needs, within a time limit.	The player must click on mud or clay only in reaction to what is said is needed, with no learning being necessary. Therefore, instruction is not well-embedded.	The motivations behind the player's digging of mud and clay are well-described. Therefore, exploration of activity is good.
Baking Clay Bricks	Chief Brick Maker	To learn how clay bricks were fired to make them weatherproof.	The player must watch as some bricks are baked and remember how long it took. They must then bake some bricks for themselves and bake them for the same length of time.	The player must click on the button after the correct time has lapsed, which is shown to the player beforehand. Therefore, instruction is not well-embedded.	The motivations behind the player's baking of clay bricks are well-described. Therefore, exploration of activity is good.
Measuring the Ziggurat	Ziggurat Architect	To learn how basic maths and geometry must have been used in the design and construction of ziggurats.	The player must mark out a rectangle on the ground of the correct size by instructing a worker to turn or walk.	The player must instruct the worker to turn or walk at the correct times so the area is the correct size. Therefore, instruction is not well-embedded.	The motivations are related to the overall motivations of the game. Therefore, exploration of activity is good.
Calculating Processes	The King	To learn how calculations were performed to ascertain productivity rates and the most efficient way of organising workers, and how this information could be stored on cuneiform tablets.	The player must read a cuneiform tablet and determine the rates at which workers can complete different tasks and use this information to complete a new tablet.	There are several options and the player must choose the correct one, using basic mathematics to calculate the answer. Therefore, instruction is not well-embedded.	The motivations behind the player's calculating activities are well-described. Therefore, exploration of activity is good.
Performing Rituals	The King	To learn how rituals were performed throughout the year by the King and the state cult to gain the blessings of the Gods.	The player must perform rituals by observing the order of the ritual, and replicating that sequence, in a "Simon Says"-style game.	The player must click the buttons in the correct order, which is shown to the player beforehand. Therefore, instruction is not well-embedded.	The motivations behind the ritual are well-described. Therefore, exploration of activity is good.

Table 23. Description and analysis of the mini-games in the chosen serious game concept

b) Analysis of Historical Activity

The methodology proposed in Chapter 6 was also applied to the chosen concept to evaluate its strength at presenting and exploring historical activity, and their link with the serious game mechanics, to achieve effective bridging of activity contexts. This analysis is shown in Table 24.

The chosen concept particularly aims to improve both the upward and downward contextualisation of the ziggurat-building activity. The upward contextualisation is improved by better defining the setting of the gameplay by showing more of the city where the game takes place. It is also explored more through the speech system, where the King speaks to the player about the different motives behind the construction of the ziggurat, and through the different mini-games. The downward contextualisation is improved by exploring the different construction processes through the mini-games and their mechanics, where each mini-game focuses on one aspect of the historical activity in greater depth. It is anticipated that this improved exploration of historical activity, embedded in the game mechanics, will help improve the extent to which it can achieve bridging of activity contexts for the player, and so better achieve meaningful integration of play and learning.

Activity Element Type	Activity Element Description	Serious Game Implementation
Activity	Building of the ziggurat	The player performs this activity by managing the labour division of the different construction processes through the assignment of workers to each process, as well as through the minigames, where one of the process envoys engages the player with a speech and the player must complete a short challenge relating to that construction process. Progress is shown by the graphics of the ziggurat which show increasing levels of completion. Upon completion of the activity, the player views their performance. Some community relation is briefly mentioned through different NPC conversations. No rules of the activity are shown. Context is shown through the intro cinematic, through the background graphics in the city gameplay, and the intro speech. Meaning and motives are explored through the intro speech of the King character.
Activity	Performing of religious ceremonies	This activity is not performed by the player. However, it is referred to through text during some of the mini-games and the final speech of the King. It is explained that the ziggurat will be used as a tool in this activity. Context is shown through the text, which explains the importance of properly conducting ceremonies at certain times throughout the year.
Subject	Governor of the city	The player plays as this actor and can therefore also role play. However, this actor is otherwise not presented.
Object	Ziggurat ruin at Ur	The ziggurat ruin at Ur is shown through simple 2D graphics in the intro cinematic and as a background to the menu.
Object	Ziggurat	The player completes the building of the ziggurat. It is shown through simplified 2D graphics at different levels of completion, as well as through animations representing each of the construction processes.
Labour division	Workers	The player assigns the workers to each process. They are shown with simplified 2D graphics in animations for each of the construction processes.
Labour division	Construction process envoys	An envoy for each construction process is shown through a 2D portrait in the mini-game speech and mini-game result. The envoys form part of the labour division aspect of the ziggurat construction activity. The envoys act as guidance characters, explaining the rules of the mini-game and giving feedback afterwards.
Motive	The King	The king is shown through a 2D portrait in the intro speech, as well as being used in the same way as the construction process envoys in the mini-game speech and mini-game result. The King acts as a guidance character for the entire game, explaining the goals and rules and giving feedback, and can also act as the guidance character for mini-games.
Motive	The Gods	The Gods are mentioned by the King during the text of the intro speech as being a crucial part of his motive for building the ziggurat.
Setting	Ancient Sumerian city	The city is shown through simplified 2D graphics in the background of the city gameplay, with some simple animations.

Table 24. Activity analysis of the chosen concept

An analysis of the chosen concept and its presentation and exploration of historical activity, using the methodology presented in Chapter 6.

7.4. Development of the Prototype Serious Game for Assyriology

As described in Section 7.1, the third step of the Assyriology serious game redesign process is to produce a working software prototype of the designs so far developed, equivalent to stage 9 of Tang and Hanneghan's (2014) serious game design methodology.

It was decided that this prototype should be developed in Adobe Animate[24], the successor to Flash, for three reasons. Firstly, Animate allows fast and efficient production and prototyping of all the interactive game elements and systems included in the game design described so far, presented through simple animated 2D graphics. Thanks to its user-friendly drawing and development tools, development can be completed faster than many other, more feature-rich, engines or software packages. Secondly, Animate exports the resulting application in the "*.swf" format, which is widely recognised and is easily shared through the internet. Finally, Animate also allows the use of user analytics, allowing the tracking of player interactions with the game, when it is played from anywhere in the world, so long as the player has an internet connection.

All the game design elements, mechanics, and systems, including objectives, characters, narrative, and all ten mini-games, described in the previous section were implemented into a working prototype game. Several screen captures from this prototype are shown in Figure 43.

[24] https://www.adobe.com/products/animate.html

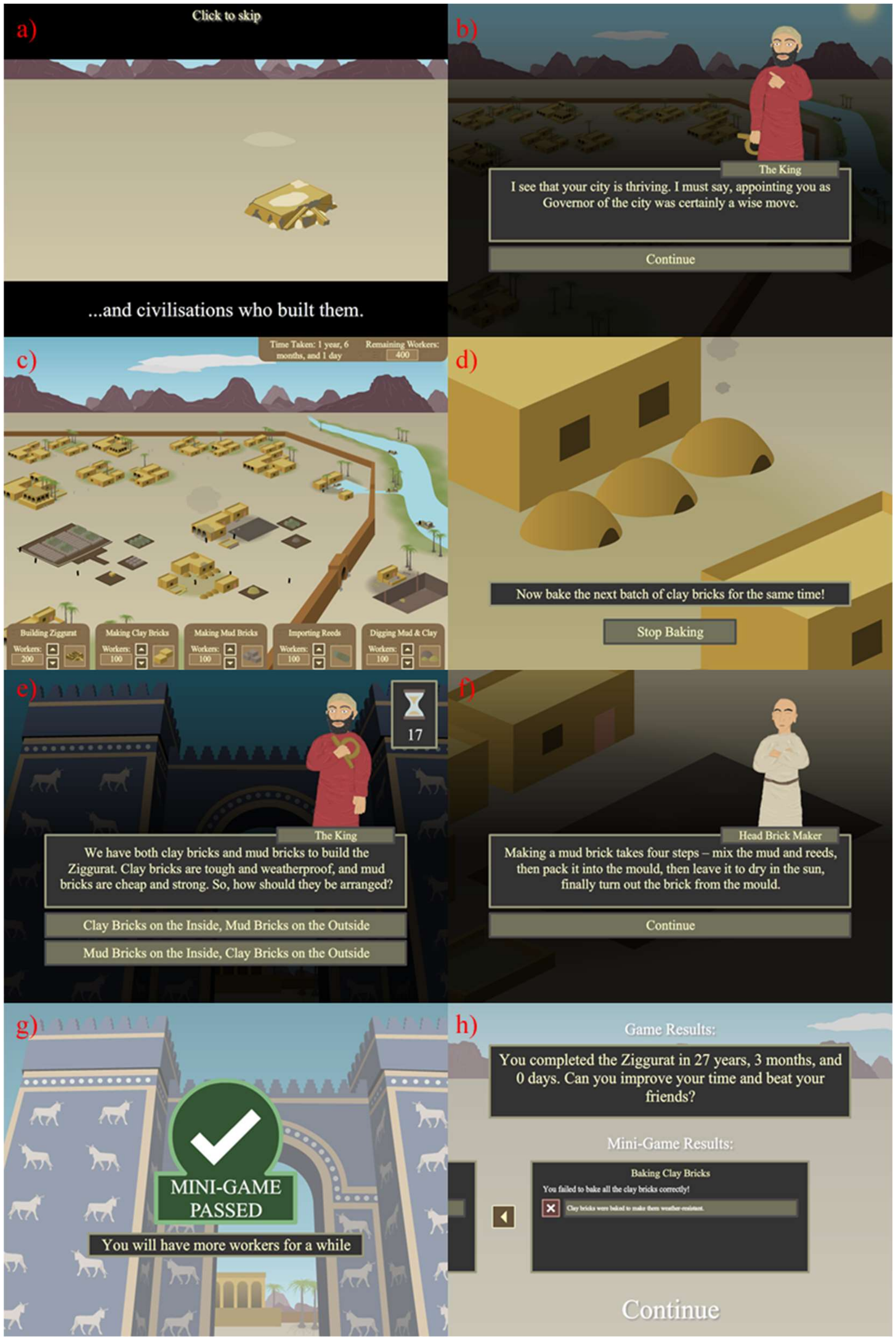


Figure 43. Screen captures from the developed Assyriology serious game prototype

a) The intro cinematic; b) the game tutorial shown through a conversation with the King character; c) the construction gameplay; d) the Baking Clay Bricks mini-game; e) the Questions with the King mini-game; f) the learning material presented in the Making Mud Bricks mini-game through a character conversation; g) the reward for successfully completing a mini-game; h) the results screen after completing the game.

The prototype game was calibrated so that the game balancing was similar to the original serious game produced by the British Museum, although game sessions were naturally longer due to the mini-games and character conversations. Finally, using the analytics systems available in Animate, event logging was added to most user interactions in the game, so that player performance and behaviours could be measured from within the field. More information will be given on the specific interactions tracked using these analytics in the next section, where an in-the-field user test will be detailed.

7.5. User-Test of the Prototype Serious Game for Assyriology

7.5.1. Test Objectives

As described in Section 7.1, the fourth and final step of the Assyriology serious game redesign process is to evaluate the developed prototype against its stated objectives by performing an initial stage of user testing. This testing is performed through an online trial where members of the public can freely access and play the serious game prototype, and their performance and feedback are measured. The primary objective of this user-test is to evaluate the extent to which the prototype, at its relatively early stage of development, is able to achieve its objectives as a serious game for heritage. This primary objective can be broken down into three sub-objectives. Sub-objective A is to determine the extent to which the prototype is a fun and engaging gameplay experience that people enjoy interacting with. Sub-objective B is to determine the extent to which the serious game is an effective educational tool, causing players to learn the instructional content and demonstrate the outcomes of that learning. Finally, sub-objective C is to gain verbal feedback from players about the game and determine the extent to which the prototype is able to cause effective bridging of activity contexts, causing the players to reflect upon and empathise with the historical activity of building ziggurats and the actors who were involved. It is worth noting that in this testing, the prototype will be tested in isolation and will not be compared against another serious game, such as the original Building a Ziggurat serious game, upon which the redesign process was based. This is because a comparison of the base game against the redesigned game would include too many other conflating variables, such as the specific characteristics of the two serious games, so would not provide an effective evaluation of the methodology presented in Chapter 6.

7.5.2. Test Methodology

To perform an online user-test, where members of the public could freely access and play the serious game prototype, it was uploaded to an online game repository website for a limited period of time. The chosen publication target for this purpose was Newgrounds[25], a popular Flash repository website where any members of the public are free to upload animations and games in Flash format and are free to watch and play those uploaded by others. While the website is mostly used for entertainment games, rather than educational games, the website was chosen as the publication target for three reasons. Firstly, because of the ease and simplicity with which the prototype could be uploaded or taken down at any point as decided by the test coordinator. Also, Newgrounds is a well-known and popular website that attracts large numbers of viewers. Therefore, the number of members of the public who would play the prototype in only a short period of testing was higher than for other similar websites. Finally, because most of the games found on Newgrounds are designed for entertainment, this will provide an especially effective test of the extent to which the prototype creates an enjoyable

[25] https://www.newgrounds.com/

gameplay experience. However, the context of use that the prototype is being tested within is clearly very different from the intended context of the original game developed by the British Museum. This is simply a factor that must be taken into account when considering the results and will be further discussed in Section 7.5.4.

The prototype serious game was uploaded to the Newgrounds repository site for a six-week period in February to April 2019. The listing for the prototype did not mention the fact that it was educational or a test, but simply described itself as an entertaining game about building a ziggurat in ancient Mesopotamia (as shown in Appendix III.1) to encourage more people to play the game. Once users had chosen to play, they would then have an opportunity to view the participant information sheet, giving them more information about the test and what data would be recorded and how it would be used if they proceeded to play the game, and assuring them of the anonymous and ethical treatment of that data (as shown in Appendix III.2). Participants were free to stop playing at any point by closing the internet browser window or by simply navigating to a different page on the website, and were free to play for as long and as many times as they wished. There was also no limit placed upon whether players could play one session of the game, and then come back and play another. Due to individuals not being uniquely identified by the analytics system in Adobe Animate, it was not possible to detect whether this did occur. However, due to the nature of the Newgrounds website, which hosts very large numbers of submissions, it is assumed that almost all the play sessions would have been a different individual. There were also no limitations placed upon the characteristics of the participants who played the prototype, since no demographic information was measured from participants. This lack of control over the participants is an inherent characteristic of performing such in-the-field tests and is discussed further in Section 7.5.4.

For sub-objective A, the extent to which participants found the game a fun and engaging experience was measured by asking participants to submit a rating of the game after finishing for the first time in a session, on a 5-point star-based rating scale. Additionally, in-game analytics also measured how many players started each section of the game, or where they stopped playing. For sub-objective B, the effectiveness of the serious game as an educational tool was measured by using in-game analytics to track participants' performance in each of the mini-games, thereby measuring whether they were able to successfully apply their learning. Finally, for sub-objective C, the measurement of the bridging of activity contexts is far more challenging, due to the very personal nature of the effect to be measured. An attempt was made to measure this phenomenon by inviting players to submit comments relating to what they "think it would have been like to be involved in building a ziggurat in those times", as well as general comments about the serious game prototype, through a system built into the Newgrounds host site.

7.5.3. Test Results

Over the six-week period, 402 members of the public played the prototype game, measured as the number who pressed the start button on the menu.

a) Sub-Objective A – Fun and Engagement

73 participants submitting a rating on the 5-point star-based scale for their perceived quality and fun of the prototype serious game, and the distribution of ratings is shown in Figure 44. The mean rating was 3.4 stars and the median 3 stars.

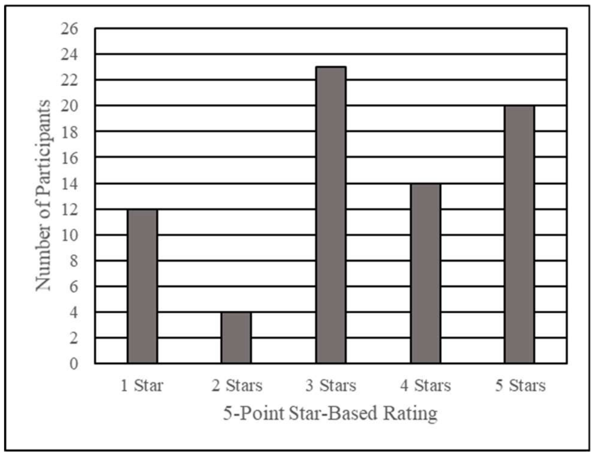


Figure 44. Distribution of participant ratings for the prototype serious game

Additionally, the numbers of participants who replayed the game multiple times in a single session and the parts of the game where participants stopped playing, are shown in Table 25 and Table 26, respectively.

Category	**Number of Participants**	**Percentage of those who played the game**
Start game 1st time	402	100.0%
Finish game 1st time	137	34.1%
Start game 2nd time	25	6.2%
Start game 3rd time	12	3.0%
Start game 4th time	7	1.7%
Start game 5th game	3	0.7%
Start game 6th time	2	0.5%

Table 25. Numbers of participants who played the prototype serious game different numbers of times

Game Section	Number of Participants who Exited	Percentage of Total
Menu	57	14.2%
Intro Cinematic	6	1.5%
Tutorial	72	17.9%
Level 1	51	12.7%
Level 2	36	9.0%
Level 3	18	4.5%
Mini-Game: Questions with the King	23	5.7%
Mini-Game: Baking Clay Bricks	9	2.2%
Mini-Game: Stamping Clay Bricks	9	2.2%
Mini-Game: Importing Reeds	8	2.0%
Mini-Game: Making Mud Bricks	7	1.7%
Mini-Game: Building the Ziggurat	6	1.5%
Mini-Game: Calculating Processes	5	1.2%
Mini-Game: Performing Rituals	4	1.0%
Mini-Game: Digging Mud and Clay	4	1.0%
Mini-Game: Measuring the Ziggurat	2	0.5%
Outro Cinematic	2	0.5%
Game Results	40	10.0%
Participant Rating Feedback	43	10.7%
TOTAL	**402**	**100.0%**

Table 26. Numbers of participants who exited the game prototype at different stages of the game

b) Sub-Objective B – Educational Effectiveness

The rates with which participants passed or failed each of the mini-games are shown in Table 27, and the rates with which participants passed or failed each of the questions specifically in the Questions with the King mini-game are shown in Table 28.

Mini-Game	Number Times Played	Number of Successes	Number of Failures	Success Rate
Measuring the Ziggurat	81	60	21	74.1%
Performing Rituals	82	56	26	68.3%
Digging Mud and Clay	104	62	42	59.6%
Importing Reeds	89	51	36	58.6%
Calculating Processes	90	49	41	54.4%
Baking Clay Bricks	85	33	52	38.8%
Making Mud Bricks	90	24	66	26.7%
Stamping Clay Bricks	207	40	167	19.3%
Building the Ziggurat	119	17	102	14.3%

Table 27. The numbers of times each mini-game was played, and either passed or failed

Furthermore, the time was recorded that participants spent looking at the post-game results screen, with feedback on the total time taken to construct the ziggurat, and their results for each mini-game, and what was learned in each mini-game. The mean time spent looking at this screen was 26 seconds.

Question Number	Question Text	Point of Instruction	Number Times Played	Success Count	Failure Count	Success Rate
1	As you know, building this Ziggurat will help to gain the favour of the Gods, and they will bless the Kingdom. So, what building should be at the top of the Ziggurat?	Within the question	95	88	7	92.6%
2	The Ziggurat will be a central monument for religious ceremonies. So, who will be allowed to climb to the top of the Ziggurat?	Within the question	74	62	12	83.8%
3	As you will know, the Moon God, Nanna, is the patron God of this fair city. So, which God(s) should the Ziggurat be dedicated to?	Within the question	103	65	38	63.1%
4	We have both clay bricks and mud bricks to build the ziggurat. Clay bricks are tough and weatherproof, and mud bricks are cheap and strong. So, how should they be arranged?	Within the question, Building the Ziggurat mini-game	69	57	12	82.6%
5	You know, this great Ziggurat was inspired by certain buildings in the city which are raised up above other buildings on great earth platforms. What buildings are they?	Within the question	76	74	2	97.4%
6	Is it true or false that to obtain mud and clay, we must trade with neighbouring Kingdoms?	Digging Mud and Clay mini-game	84	72	12	85.7%
7	Is it true or false that to obtain reeds, we must trade with neighbouring Kingdoms?	Importing Reeds mini-game	113	67	46	59.3%
8	So, you know that some of the clay bricks will be stamped with writing, but what should that writing say?	Stamping Clay Bricks mini-game	72	66	6	91.7%
9	So, you know the clay bricks we use to build the Ziggurat. What process is done to the wet clay bricks to finish them?	Baking Clay Bricks mini-game	96	57	39	59.4%
10	So, you know the mud bricks we use to build the Ziggurat. What process is done to the wet mud bricks to finish them?	Making Mud Bricks mini-game	95	63	32	66.3%
11	Those tablets that I gave you for controlling the workers when we started the building, what are they made from?	Game Tutorial	80	56	24	70.0%
12	Once the Ziggurat is completed, how often should the religious ceremonies be carried out?	Performing Ceremonies mini-game	101	86	15	85.1%

Table 28. The numbers of times each question in the Questions with the King mini-game was passed or failed

c) Sub-Objective C – Participant Comments and Activity Context Bridging

The complete set of comments left by players is shown in Table 29, including comments relating to the game as well as comments relating to the historical activity.

Participant Comments relating to the game
"Very interesting, unique, and educational game, with room to improve. Keep doing good work!"
"Nice Game!"
"Love how the minigames affect worker availability, along with the military campaigns. Would prefer the timer be a bit slower, or else have a pause/start day function."
"There's nothing stopping you from being completely [idle] for thousands of years."
Comments relating to what participants "think it would have been like to be involved in building a ziggurat in those times"
"Labour intensive."
"Terrible, as I most likely would have been a common labourer or a slave, and would have enjoyed a much worse standard of living with regards to food, shelter, clothing, medicine, education, and human rights."

Table 29. Comments left by participants on the prototype serious game

7.5.4. Test Discussion

a) Sub-Objective A – Fun and Engagement

Based on the distribution of participant ratings assigned to the prototype game, the mean rating of 3.4 stars, and the fact that 34.1% of those who started the game went on to complete it, it can be concluded that the prototype game was somewhat successful at creating a fun and engaging gameplay experience, however there is clearly room for improvement. This is quite encouraging, especially when considering that the Newgrounds website is typically populated with high-quality games designed purely for entertainment, many of which are created by professional development studios. One of the ways in which the game could be improved is to further encourage more players to play the game several times. Improving rates of replaying would also likely help to improve the educational effectiveness of the game, as players will get several chances to learn and apply the instructional content. Finally, by examining the stages of the game where players were most likely to exit, it is possible to identify stages or mini-games that are clearly causing players to be frustrated into quitting before finishing. This is clearly the case with the tutorial, which caused many players to stop before even beginning the gameplay and should therefore be shortened and streamlined. Finally, some mini-games, such as Baking Clay Bricks and Importing Reeds also had high quit rates, suggesting that these mini-games need to be revisited and streamlined, to make it clearer how to play them, reducing frustration.

b) Sub-Objective B – Educational Effectiveness

There is a wide range of differing success rates for each of the mini-games, and this gives valuable feedback for which mini-games are too easy, which are too difficult, and which need to be explained more clearly. It is observed that two of the mini-games that embed instruction in their game mechanics, Making Mud Bricks and Building the Ziggurat, had some of the lowest success rates. These could be addressed by allowing the player to make more mistakes, and providing immediate feedback, before causing the entire mini-game to be failed, or by streamlining the transmission of the instruction, so that the player is required to read less text.

The success rates for most of the Questions with the King questions were very high, which is a very encouraging point. It is particularly reassuring when considering that for many of these questions, the player learned the required information in a different part of the game, such as the tutorial or another mini-game. This shows the effectiveness of using the Questions with the King mini-game to connect together many different aspects of the game, and the historical activity that the game is exploring. Finally, it is observed that participants spent a long time reviewing their results, considering the otherwise fast-paced nature of the game and of most games found on the Newgrounds website. This therefore shows evidence for the effectiveness of giving feedback for participant performance after completing the serious game, a point that has also been stressed by other researchers (e.g. De Gloria *et al.*, 2014).

c) Sub-Objective C – Participant Comments and Activity Context Bridging

Overall, it can be stated that the participant comments left on the game were almost all very positive, and participants clearly appreciated and enjoyed the serious game. The only negative feedback were criticisms of aspects of the design, such as the speed of the game and the fact that there is no upper time limit for completing the ziggurat. This latter point, however, is still very interesting because it shows how players will explore the limits of the possibility space defined by the serious game's rules, often in ways the designer did not expect. This shows the potential of designing serious games where players can learn through their own exploration of the mechanics, rather than by being forced through a prescriptive sequence of instruction, as has also been suggested by other researchers (Champion, 2017a). Finally, the comments relating to the historical activity of ziggurat construction show that the serious game had the potential to encourage players to imagine aspects of the activity, in this case the difficulty and labour-intensive nature of it, that were in no way mentioned within the serious game itself. The second comment showed that the participant even considered the nature of the activity and the wellbeing of those historical actors in comparison with their own life and wellbeing. However, the low quantity of these comments makes any substantial conclusions impossible. It is expected that more detailed data could have been collected for the extent to which the serious game achieved bridging of activity contexts, by using more in-depth measurement techniques such as semi-structured interviews, however this was not possible given the chosen experimental design.

d) Limitations of the Test

There are several limitations of the test that should be considered when interpreting the results. Firstly, the context of the Newgrounds website is not educational, but designed for entertainment purposes. This makes it difficult to predict how players would react to the serious game in an educational context such as the Mesopotamia website for which the base serious game was originally designed. Nevertheless, the use of an entertainment context allows a more genuine and rigorous evaluation of the engagement and fun aspects of the serious game, which the prototype was judged to be quite successful at.

Next, the data that could be collected in the chosen experimental context was relatively limited, whereas more detailed results and analysis could have been gained by carrying out focus groups or interviews with participants, particularly when evaluating the extent to which the serious game achieved bridging of activity contexts. However, collecting data through in-game analytics that observed participants' behaviours and performance silently as they played, was advantageous because it removed the possibility of participants' behaviour or responses being affected by the experimental procedures.

Finally, due to the test being carried out "in the field", it was impossible to exert any control over the participants or filter who was able to play the game and submit data. This also meant there was a possibility that participants could play the game over several sessions and submit multiple sets of data. However, as has already been mentioned, it is assumed that the incidence of this will be minimal, due to the nature of the Newgrounds site.

7.6. Discussion

7.6.1. Future Development Steps

According to the 13 stages of serious game development proposed by Tang and Hanneghan (2014), the next steps that would be carried out are to refine the proposed design of the serious game for heritage, based on the evaluation performed. As has already been described, such refinements would include improving the rates for which players replay the serious game by adding more incentives and goals for doing so. The design of some of the mini-games could also be improved by altering the calibration and balancing, making the mini-games that many participants failed easier, and also by redesigning the way the instructional information is presented, to remove barriers to the learning process.

The prototype could then be altered according to the new designs and subjected to another cycle of testing. It would be advantageous to perform such tests in an educational context, which would be closer to the intended context of use of the serious game. More detailed results could be collected, such as focus groups, questionnaires, and interviews, as recommended by Birchall *et al.* (2012), although a necessary trade-off would be a reduced quantity of data. Once this iterative cycle of design, testing, and feedback has been completed a sufficient number of times, the serious game would be finalised and tested for final levels of quality and would then be ready for final release to its target audience in the intended context of use.

7.6.2. Evaluation of the Methodology

The purpose of the case-study presented in this chapter was to provide a real-world implementation of the SGH design methodology presented in Chapter 6 and so an evaluation of its effectiveness. For the analysis of both the base SGH Building a Ziggurat in Section 7.2.3

and the redesigned version in Section 7.3.5, the methodology was very useful, because it could offer insights and understanding not possible using ATMSG (Carvalho, Bellotti, Berta, *et al.*, 2015) and the Hall *et al.* (2014) model, both of which are considered the state of the art in serious game conceptual frameworks. It created an awareness of both games' exploration of historical activity, why the base game was weak in this regard, and how the redesigned serious game was improved.

Furthermore, the methodology presented in Chapter 6 was also useful for the process of redesigning the serious game for heritage in Section 7.3. Here the paradigm of activity theory was very effective for enumerating and exploring the instructional content in a manner that assisted the creative process of manifesting the content in the serious game, such that user meaning-making was also supported. The use of the model of historical content, presented in Chapter 3, also made it easier to enumerate, analyse, and decide how each aspect of the historical instructional content should best be presented through the SGH.

However, one aspect that has not been fully addressed is whether the redesigned serious game can indeed achieve a greater level of activity context bridging than the base game, although the analysis would suggest that it could. This is due to the nature of the user test that was carried out, which focused on evaluating the fun and engaging nature of the gameplay and the effectiveness of learning using quantitative metrics aggregated across many participants, rather than investigating the effects of playing on individual participants. This would therefore be an important feature of any further work on developing this serious game for heritage and for evaluating the presented methodology.

Therefore, overall this case-study has shown that the methodology presented in Chapter 6 is indeed effective and valuable at creating insight and assisting in both the analysis and design of serious games for heritage.

7.7. Conclusions

7.7.1. Chapter Conclusions

In this chapter, a case-study was carried out to evaluate the effectiveness of the methodology for analysing and designing serious games for heritage, presented in Chapter 6, to fully address the fourth and final secondary research question. It was decided that, to reduce the time and resources required, the methodology should be applied through a process of analysing and redesigning an existing serious game for Assyriology. For this purpose, the SGH Building a Ziggurat (The British Museum, 2006a) was selected as an ideal target due to its engaging gameplay but its lack of instructional content.

Analysis using two state-of-the-art serious game frameworks showed that Building a ziggurat indeed had engaging gameplay, but that the instructional content was not embedded well in the mechanics. The presented methodology was able to show that the serious game presented limited exploration of the historical activity, and that it was poor at activity context bridging through the serious game mechanics, and therefore also supporting meaning-making. A redesign process was then carried out through several steps; an enumeration of the instructional content presented by the Mesopotamia (The British Museum, 2006b) website, an analysis and exploration of this content through the lens of activity theory, a process of serious game brainstorming in conjunction with an Assyriology field expert, and concept development, storyboarding, and selection in conjunction with the project supervisor. A final stage of analysis using the proposed methodology showed how the redesigned SGH should be greatly improved in terms of exploring historical activity.

A prototype serious game was developed according to the proposed designs, which was evaluated through an online user test. It was made available to the public over a period of time, and in-game player behaviour and performance were measured using in-game analytics, as well as a post-game rating and comment system. The results showed that the serious game prototype was relatively well-received by players, and the mini-game structure was effective at exploring and instructing different aspects of the historical activity. However, due to the lack of focused questioning with individual participants, it was difficult to ascertain the extent to which the redesigned SGH could achieve effective bridging of activity contexts. Nevertheless, the methodology was overall deemed quite successful for providing insight throughout both the analysis and design processes.

7.7.2. Future Work

Future work in this direction could be directed towards how the bridging of activity contexts might be measured using game learning analytics and objective performance measures. The user-test presented in this chapter showed the advantages of such a non-invasive approach, however it is unclear how such an internal and affective process such as the making of personal meaning and the bridging of activity contexts might be measured only through objective measures. Champion *et al.* (2012) found that the complexity and context-sensitivity of interactions in serious games for heritage made such an approach very challenging, but it may yet prove to be a worthwhile direction for research.

Additionally, future work can also continue the process of redesigning the serious game for Assyriology begun in the present case-study. Such work would involve applying the results of the user test to iterate the serious game design, creating a new prototype, and undergoing a new stage of user testing. This testing would ideally investigate individual players' interactions with the serious game prototype more deeply. Then, following a process of final integration and quality assurance, the SGH would be ready for release and application within its target context.

7.7.3. Applications to the Thesis

A methodology to aid in the analysis and design of serious games for heritage has now been presented and shown to be a promising approach, which can be drawn upon in the final chapter of this thesis, which will present the overall conclusions of the project. Furthermore, this methodology will help to shape the future directions of this research project as well as that of the wider academic field.

Chapter 8 Conclusions and Future Work

8.1. Summary of the Thesis

Chapter 1 introduced the topics and areas most relevant to the project, as well as a statement of the primary aim of the thesis, which was to investigate how serious games for heritage could be designed and developed to present learning content on ancient history, through a case-study in the field of Assyriology and ancient Mesopotamian history. It also detailed an interview conducted with an Assyriology field expert to determine the challenges and opportunities specific to applying serious games to the field.

A review of the bodies of academic literature most relevant to the project was then described in Chapter 2. Gaps in the reviewed literature were identified, which formed the basis of the thesis research questions. In Chapter 3, to address the first secondary research question, a model was proposed to define historical content presented through video games, the different ways it can be manifested in the video game medium, as well as the associated learning outcomes.

Chapter 4 addressed the second secondary research question by applying the theories of constrained virtual environments to serious games for heritage and described a game engine to develop serious games based upon these theories. The implementation of a constrained virtual environment version of one level from a serious game for Assyriology, Discover Babylon, was documented. In Chapter 5 this constrained environment implementation of the Discover Babylon level was experimentally tested and compared against the original level through a two-group experiment, to address the third secondary research question. The results showed that participants in both groups had similar levels of presence, enjoyment of the game, and perception of its level of quality, and were equally likely to pursue further learning on the subject matter. Finally, a set of initial guidelines was established, to assist future efforts in creating constrained virtual heritage environments.

Based on the interview with an Assyriology field expert, Chapter 6 discussed how serious games for heritage should best be applied to the field of Assyriology and Mesopotamian history, to partly address the fourth secondary research question. Based on these proposals, a methodology was proposed for analysing and designing serious games for heritage, utilising activity theory. Finally, in Chapter 7, the methodology was shown to be promising by applying it to the analysis and redesign of a serious game for Assyriology, originally produced by the British Museum, to fully address the fourth secondary research question.

8.2. Conclusions of the Manifestation of Historical Content in Video Games

In Section 1.5.3, two thesis themes were introduced, which were revisited several times throughout the thesis. The first of these was the concept of manifestation of cultural heritage and historical content within video games, what types of video games this content could be found in, the characteristics of those manifestations, and the associated learning outcomes. It was noted that many serious games and virtual heritage applications tend to focus heavily on the audio-visual aspects of presenting historical content, and less on its meanings, perceptions, and significance. Furthermore, in the literature review in Chapter 2 it was found that there was a lack of definitions or models focusing on this concept.

A model was proposed in Chapter 3 to offer such a definition of manifestations of historical content in video games. This model allowed the description at a game content level, rather than at a game level, which enabled historical content in any type of video game to be described, whether it is a serious game, game modification, or commercial game developed for entertainment purposes, using a common "vocabulary".

Next, it was found in Chapter 4 that the use of reduced-fidelity game engine technology, such as constrained virtual environments, necessitates a deep understanding of how historical content is presented in video games and how it is interpreted by users. This includes concepts such as how spatial information is presented through virtual environments, presentation of historical uncertainty and lack of knowledge, differing levels of historical accuracy and authenticity, and user experience of presence, sense of place, and of other cultures and belief systems.

Furthermore, the results of the Discover Babylon experiment conducted in Chapter 5 showed how participants reacted differently to different types of historical content presented to them, with many stating a dislike of content presented through large pieces of text, and a preference for content manifested through game mechanics and naturalistic interactions. Finally, the methodology presented in Chapter 6 for designing and analysing serious games for heritage gave a practicable means of designing and implementing such types of historical content into those games.

8.3. Conclusions of the Meaningful Integration of Play and Learning in Serious Games for Heritage

The second thesis theme described in Section 1.5.3 was how serious games for heritage can be designed, such that the user activities of playing and learning are seamlessly integrated together in a way that also enables and assists users to create their own meanings from the content, based on their past knowledge and experiences, in a process of meaning-making. This concept was therefore referred to as the "meaningful integration of play and learning". It was proposed that tight integration of play and learning is the best way to ensure serious games manage to be effective at both achieving their learning outcomes and also being fun and engaging gameplay experiences. Furthermore, the concept of meaning-making has found great success in its applications to historical learning within the museum field, hence its intended inclusion in serious games for heritage.

In the literature review in Chapter 2, it was found that some conceptual frameworks or methodologies for serious games can, to some extent, address the concept of seamlessly integrating play and learning together. However, none of the reviewed frameworks addressed the specific requirements of history, nor the concept of meaning-making. In Chapter 3, through considering the different ways in which historical information can be manifested through a video game's mechanics and systems, it was proposed that the concept of procedural rhetoric, whereby the game's rules and mechanics are designed to elicit certain reactions and cause learning of defined content, might be a useful paradigm for achieving meaningful integration of play and learning in serious games for heritage. However, some issues were also identified with this approach, and little research has yet been done in this direction.

It was proposed in Chapter 4 that it should be possible to achieve meaningful integration of play and learning using a wide range of interfaces, game engines, and technologies, including constrained virtual environments. These notions were further reinforced by the results of the Discover Babylon constrained environment experiment in Chapter 5, where many participants, having played either the 3D or constrained versions of the level, expressed a strong preference for the parts of the game where the learning and gameplay were more closely integrated in ways that made greater use of affect.

The methodology in Chapter 6 attempted to aid designers of serious games for heritage to achieve meaningful integration of play and learning, through activity theory and the concept of activity context bridging, which has already been used as a paradigm for achieving meaning-making using ICT and technology in museum displays. Finally, in Chapter 7, the methodology was able to show how a chosen serious game for Assyriology was weak at achieving bridging of activity contexts and suggested that, after being redesigned, the serious game would be superior in this regard. However, further testing is required to better determine whether the redesigned serious game is indeed more successful in this manner.

8.4. Implications for the Analysis, Design, Development, and Evaluation of Serious Games for Heritage

8.4.1. Implications of the Model of Historical Content in Video Games

The first major implication of the model of historical content in video games, presented in Chapter 3, is that it allows the identification and analysis of historical content in commercial games and the associated learning outcomes, as was demonstrated in Section 3.4. This aids the use of entertainment games for educational purposes, and it is anticipated that future models, methodologies, and approaches to utilising commercial video games in history education can build upon the work presented here.

The second major implication of the model is that it can be built upon and used by other methodologies as a generalised way of defining how a piece of historical information can be manifested in a video game, as seen by its use in the SGH methodology presented in Chapter 6. It is expected that it can be further utilised and extended by other frameworks and methodologies, for designing and analysing serious games for heritage, or for other purposes not anticipated here.

8.4.2. Implications of Constrained Virtual Environments for Serious Games for Heritage

It is proposed that the concept of constrained virtual environments, developed and applied to serious games for heritage in Chapter 4 and tested experimentally in Chapter 5, represents a viable development approach. It allows SGsH to tackle the challenges of budget and resource requirements, while still allowing them to create a strong sense of presence for users and gain their interest and attention to the subject matter through engaging gameplay. Furthermore, this work also demonstrates how the reliance of serious games for heritage and virtual heritage applications on the state-of-the-art in games engine technology, especially graphical technology, is often not necessary, can be unrealistic, and may even compromise the serious game's ability to achieve its goals. It demonstrates the potential of using game engines, graphics technology, and design philosophies other than simply attempting to represent the past through 3D photorealistic objects and environments in as high-fidelity visualisation as possible. It is then worth noting that this could be achieved in other ways than only those shown in Chapter 4; the environments developed in this project are only one possible form of constrained environment, and it is anticipated that this concept can be built upon in many different directions.

It is proposed that developments in this direction will help to address some of the present issues in serious games for heritage, including the overreliance on audio-visual presentation, and the under-representation of the meanings, interpretations, and significance of historical material. Other issues that may also be tackled include how to represent inappropriate, violent, or highly sensitive historical material, as well as how to represent the concept of historical uncertainty and a changing state of knowledge through a medium that traditionally can only represent a single, definite state of being.

8.4.3. Implications of the Methodology for Designing and Analysing Serious Games for Heritage

The methodology for designing and analysing serious games for heritage, presented in Chapter 6, endeavoured to enable seamlessly integrated playing and learning activities, while also supporting user meaning-making, making them more effective as tools for cultural learning, empathy, and even changing player attitudes and expanding cultural horizons. This methodology attempted to integrate three approaches which are seen as highly important within the field of serious games for heritage. The first is to move towards developing more applicable and practicable methodologies for serious games that can be followed by diverse teams in real development scenarios, rather than only serving as a high-level conceptual framework. The second was to move towards serious games that find better ways of integrating play and learning, so that they can be truly effective as both games and learning tools, and neither aspect is compromised. Finally, to adopt and integrate the concept of meaning-making into serious games for heritage, which has been shown to be an important and influential paradigm in the history and heritage sector. It is anticipated that the methodology will aid those involved in designing, analysing, and evaluating serious games for heritage, and it is also proposed that future methodologies and frameworks should take these concepts on board and build upon them, especially in the development of new methods for evaluation.

8.5. Implications for Virtual Heritage and Interactive Technology in History and Cultural Heritage

It is proposed that the results and conclusions of this project can be generalised to the wider fields of virtual heritage and applications of interactive technologies to history and cultural heritage through one primary approach. This is the concept of constrained virtual environments and the effect of carefully and strategically reduced visual fidelity of presentations of history, particularly virtual heritage environments. The work presented in this project has shown that it is possible to successfully present historical information through means of presentation other than high-fidelity photorealistic 3D polygonal models. As Foni *et al.* (2010) proposed, there are many different feasible means of presenting historical material, each with their own advantages and disadvantages. Although the authors concluded that 3D polygonal models may offer the best compromise between different factors for different interest groups, this work has shown that it is worthwhile exploring other approaches, which may still be able to achieve the defined objectives, while also requiring less resources to realise.

8.6. Future Work

8.6.1. Future Work as an Extension of the Thesis

There are some aspects of future research that can be undertaken, aiming to extend the work completed within this thesis. The first of these is to apply the model of historical content in video games, presented in Chapter 3, to additional historical commercial games. In doing so, methods and best practices should be further developed for the model's use in analysing historical content in such games for educational use.

Next, serious games for heritage, for Assyriology or for other fields, should be developed and evaluated from the ground up using the principles, techniques, and guidelines for constrained virtual environments developed in Chapter 4 and Chapter 5. By embracing the concept of constrained environments from the beginning of the design process, the resulting serious games would be able to best utilise and exploit the opportunities of the format while also best overcoming its challenges. This process should then also build upon and extend the guidelines for the design of constrained virtual heritage environments introduced in Chapter 5. Furthermore, evaluation studies should be undertaken to analyse the performance of constrained virtual environments in serious games for heritage, focusing on their potential for learning and participant perceptions of the historical environments and the cultures and heritage encountered. Evaluation should also focus on the measurement of concepts such as participant experience of embodiment, spatial cognition, and cultural presence in the environments.

Finally, future work should also include the further iterative design, development, and evaluation of the redesigned serious game for Assyriology presented in Chapter 7. The results documented from the first user test should be fed back into the design stage to improve the serious game, so that a new prototype can be developed and tested in another stage of evaluations. These evaluations would ideally include methodologies and measurement techniques such as participant interviews, questionnaires, and focus groups and would specifically investigate the effectiveness of the serious game at achieving bridging of activity contexts with the historical material and supporting player meaning-making.

8.6.2. Future Work within Associated Research Fields

Furthermore, by considering the work completed in this thesis within the context of the related academic fields, it is possible to recommend aspects of future research that are most promising in a more general sense.

Firstly, deeper considerations and analysis should be directed towards the potential of commercial video games for presenting cultural heritage and supporting historical learning, especially given the popularity and wide proliferation of such games. This should lead to the development of improved analysis and evaluation techniques for utilising such games in educational settings.

Next, further research should be committed to different approaches for capturing, documenting, and presenting historical material through serious games for heritage, which do not utilise high-fidelity photorealistic 3D polygonal models. It is then also important to critically analyse how different forms of presentation affect users' perceptions and interpretations of the historical information, as well as the resulting learning. Within this thesis, the work on constrained virtual environments has shown the relative success of this particular approach, however it is important to stress that this represents only one approach in a large possibility space, that should be further explored. Furthermore, research should also be conducted into the design and development of historical virtual environments that aim to recreate the phenomenological and hermeneutic experiences of those historical places. These experiences include the meanings and perceptions of the environments themselves, as well as the culturally and historically significant actors and activities that take place within them.

Finally, future research should develop further methods for analysing, designing, developing, and evaluating serious games for heritage, whether for Assyriology or for other historical fields. Such methods should focus on practicable methodologies that can be implemented in real-world development settings, as well as how to go about designing serious games that are successful as both effective learning tools and as games offering engaging and fun entertainment experiences. At the same time, such methods should also focus on how to integrate the concept of meaning-making, thereby resulting in serious games for heritage that support players in connecting with historical content through their own personal experiences, values, and meanings.

Appendix I Constrained Environment Experimental Documents

1. Information Sheet and Consent Form

The following form is the information sheet and consent form given to participants at the beginning of the constrained environment experiment:

Participant Information Sheet

GRAPHICAL REPRESENTATION OF HISTORICAL EDUCATIONAL GAMES

This project is formed of experiments looking into presence, place and learning in historical educational videogames as part of a PhD being carried out in the Department of Electronic, Electrical and Systems Engineering in the University of Birmingham.

The aim of the experiment is to explore how different graphical representations affect a user's interaction with, enjoyment of, and learning from a historical educational videogame.

The study will require you to play a level of a videogame set in the ancient Mesopotamian city of Uruk in the 4th millennium BC.

You will be introduced to the game and the control scheme by the researcher.

Your aim is to complete the level through the goals presented within the game. You should feel free to explore the game world and take the level at your own pace – imagine you are completing the game for fun in a museum setting.

You will be asked to complete some paper questionnaires and a short interview, from which an audio recording will be taken.

You will also be contacted by email in 3 months' time and be asked to complete a short follow-up questionnaire, which will be completed online.

Confidentiality and data security

Your data will be treated as confidential and you will be assigned a unique identifying code which will be used to identify your data. For this experiment, data to be collected will be age, gender and a contact e-mail. No other personal data is required (no names, ethnicity, etc.).

The results of the experiment will be stored electronically on secure University of Birmingham servers and paper copies will be destroyed.

If the results prove interesting and noteworthy, then we may decide to produce a paper for publication in a journal or a conference. You can decide not to release your data for this purpose (which would constitute withdrawal from the study) by e-mailing the lead experimenter by 1st May 2018.

Contact details

Laurence Hanes (LXH519@student.bham.ac.uk) – **PRIMARY COORDINATOR**
Robert Stone (R.J.Stone@bham.ac.uk)

Consent Form

GRAPHICAL REPRESENTATION OF HISTORICAL EDUCATIONAL GAMES

Fair Processing Statement

This information is being collected as part of a series of experiments looking into presence, place and learning in historical educational videogames as part of a PhD being carried out in the School of Electronic, Electrical and Systems Engineering in the University of Birmingham.

The information which you supply and that which may be collected as part of the research project will be entered into a database and will only be accessed by authorised personnel involved in the project. The information will be retained by the University of Birmingham and will be used for the purpose of teaching and research. It may form part of a publication in a technical journal or other forum.

By supplying this information, you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 1998. No identifiable personal data will be published.

Statements of understanding/consent

- I confirm that I have read and understand the participant information sheet for this study. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.
- I understand that, should the results prove worthy of publication, I will be given the opportunity to either accept or reject the invitation for my results to be used. If I choose to reject this invitation, I understand that his constitutes withdrawal from the experiment and that I am free to do this without giving any reason. If I withdraw my data will be removed from the study and will be destroyed.
- I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.
- Based upon the above, I agree to take part in this study.

Name, signature and date

Name of participant:	Signature:	Date:
....	....	....
Name of researcher/individual obtaining consent:	Signature:	Date:
....	....	....

A copy of the signed and dated consent form and the participant information sheet should be given to the participant and retained by the researcher to be kept securely on file.

2. Pre-Game Questionnaire

The following form is the questionnaire given to participants before starting the game for the constrained environment experiment:

Pre-Game Questionnaire

INSTRUCTIONS

Fill in lines with text: my answer .

Mark check boxes (☐) with a tick or cross (☑ or ☒)

Mark scales by shading in one of the gaps, e.g.:

1 2 3 4 5

DEMOGRAPHIC INFORMATION

1. Age: __________

2. Gender: ☐ Male ☐ Female ☐ Other ☐ Rather not say

3. Contact email address: ______________________________

4. University department: ______________________________

5. How familiar are you with the history of ancient Mesopotamia?

Not at all — Very much

6. How often do you play videogames? *If you answered "Not at all", skip forward to question 15.*

☐ Not at all ☐ Not very often ☐ Fairly often ☐ Very often

7. How often do you play videogames with 2D graphics?

☐ Not at all ☐ Not very often ☐ Fairly often ☐ Very often ☐ Don't Know

8. How often do you play videogames with 3D graphics?

☐ Not at all ☐ Not very often ☐ Fairly often ☐ Very often ☐ Don't Know

9. Approximately how long have you been playing videogames for? ______________

10. On which devices do you play videogames?

☐ PC ☐ Home console ☐ Handheld console

☐ Smartphone ☐ Interactive TV ☐ Arcade

☐ Virtual reality ☐ Other: ______________________________

11. What types of videogames do you play?

☐ First-person shooters ☐ Fighting games ☐ Role-playing games

☐ Racing games ☐ Simulation games ☐ Strategy games

☐ Sports ☐ Arcade ☐ Puzzle

☐ Other: ____

12. When you play videogames, how long (on average) are your play sessions?

____

13. How much do you agree with the statement *"when I play videogames, I often get completely immersed and sucked in"*?

Fully disagree Fully agree

14. How much do you agree with the statement *"when I play videogames, I often don't realise how much time has passed"*?

Fully disagree Fully agree

Please continue to question 15.

ANCIENT MESOPOTAMIA TEST QUESTIONS

Following is a set of questions to test your knowledge of ancient Mesopotamia, specifically the ancient Mesopotamian city of Uruk, around the time of 3000 BC. Don't worry if you don't know the answers, simply mark "don't know". Try not to guess answers you don't know.

15. True or false, in the city of Uruk around 3000 BC, when farmers produced a surplus it would be appropriated by the state?

☐ True ☐ False ☐ Don't know

16. What is the name of the system used by Mesopotamian farmers to bring water from rivers to the fields?

______________________________ ☐ Don't know

17. True or false, by 3000 BC, horses were an important animal in Mesopotamian society?

☐ True ☐ False ☐ Don't know

18. True or false, in Uruk around 3000 BC, many workers would specialise solely in a craft, such as pottery or textiles?

☐ True ☐ False ☐ Don't know

19. True or false, carved stone cylinders were rolled across clay tablets for decorative purposes?

☐ True ☐ False ☐ Don't know

20. In which millennium did writing first appear in Mesopotamia?

______________________________ ☐ Don't know

21. True or false, according to the Epic of Gilgamesh, Gilgamesh was once the king of the Mesopotamian city of Uruk?

☐ True ☐ False ☐ Don't know

22. True or false, throughout ancient Mesopotamia, writing first developed as a book-keeping tool for recording wages and the flow of goods?

☐ True ☐ False ☐ Don't know

23. What was the primary material used for writing on in ancient Mesopotamia?

______________________________ ☐ Don't know

24. True or false, all children throughout Mesopotamia would learn to read and write?

☐ True ☐ False ☐ Don't know

25. What building was situated at the top of a Mesopotamian ziggurat?

_____________________________ ☐ Don't know

26. Aside from wheat and barley, why was sesame also an important crop throughout ancient Mesopotamia?

_____________________________ ☐ Don't know

27. True or false, most marsh dwellers living outside the ancient city of Uruk lived in houses constructed from reeds?

☐ True ☐ False ☐ Don't know

28. Name a reason why rivers were important to life in the ancient city of Uruk.

_____________________________ ☐ Don't know

29. True or false, by 3000 BC the dominant language spoken in the city of Uruk was Akkadian?

☐ True ☐ False ☐ Don't know

30. What is an "ugula" in Mesopotamian society?

_____________________________ ☐ Don't know

31. True or false, the rivers of Mesopotamia would flood on a seasonal basis?

☐ True ☐ False ☐ Don't know

32. Why might people have slept on their roofs during summer in ancient Mesopotamia?

_____________________________ ☐ Don't know

33. True or false, in the ancient city of Uruk, most scribal students were boys?

☐ True ☐ False ☐ Don't know

34. What name is given to Mesopotamian temples divided into three sections?

_____________________________ ☐ Don't know

35. True or false, Mesopotamians used leather made from sheep and goat skin?

☐ True ☐ False ☐ Don't know

36. How do archaeologists know of the widespread use of baskets in ancient Mesopotamia?

_____________________________ ☐ Don't know

37. What are the main two rivers that flow through Mesopotamia?

_____________________________ ☐ Don't know

_____________________________ ☐ Don't know

38. True or false, pastoral nomads would visit Mesopotamian cities to trade goods?

☐ True ☐ False ☐ Don't know

End of Pre-Game Questionnaire

3. Game Information Sheets

3.1. 3D Environment Group

The following form is the information sheet given to participants in the 3D Environment group before starting the game for the constrained environment experiment:

Game Instruction Sheet

<u>GAME STORY</u>

Your colleague, *Professor Dex*, has travelled back in time to ancient Mesopotamia, and it's having disastrous consequences in the present day. You must stop him! You have managed to travel back to the city of Uruk in 3100 BC, and have assumed the body of a twelve-year-old scribal student named *Taribi*. You must explore the city of Uruk, speak to characters, and complete challenges to succeed in stopping *Dex* from causing even more harm!

You should feel free to explore the game world and take the level at your own pace – imagine you are completing the game for fun in a museum setting.

<u>CONTROLS</u>

You use the keyboard to control the game. You can move *Taribi* using the W, A, S, and D keys, and interact using the Enter and Numpad keys. Below is the button layout:

Use the headphones provided to hear the game sound:

At some points in the level you will be shown cutscenes, which will explain more of the story. You can press any button to skip the cutscenes. However, for the purpose of this test, it is recommended that you do **<u>not</u>** skip them, as they will help to explain what you need to do next.

If at any time you feel confused or have any questions, just ask the experiment coordinator.

3.2. Constrained Environment Group

The following form is the information sheet given to participants in the Constrained Environment group before starting the game for the constrained environment experiment:

Game Instruction Sheet

<u>GAME STORY</u>

Your colleague, *Professor Dex*, has travelled back in time to ancient Mesopotamia, and it's having disastrous consequences in the present day. You must stop him! You have managed to travel back to the city of Uruk in 3100 BC, and have assumed the body of a twelve-year-old scribal student named *Taribi*. You must explore the city of Uruk, speak to characters, and complete challenges to succeed in stopping *Dex* from causing even more harm!

You should feel free to explore the game world and take the level at your own pace – imagine you are completing the game for fun in a museum setting.

<u>CONTROLS</u>

You use the trackball to control the game. You can move the cursor with the ball and interact with the left button. Below is the button layout:

Below is an image of the cursor and the different items that can be interacted with:

Use the headphones provided to hear the game sound:

At some points in the level you will be shown cutscenes, which will explain more of the story. You can press the button to skip the cutscenes. However, for the purpose of this test, it is recommended that you do **<u>not</u>** skip them, as they will help to explain what you need to do next.

If at any time you feel confused or have any questions, just ask the experiment coordinator.

4. Post-Game Questionnaire

The following form is the questionnaire given to participants after completing the game for the constrained environment experiment:

Post-Game Questionnaire

INSTRUCTIONS

Fill in lines with text: *my answer* .

Mark check boxes (☐) with a tick or cross (☑ or ☒)

Mark scales by shading in one of the gaps, e.g.:

1 2 3 4 5

GAME EXPERIENCE

1. How much did you enjoy the level you played?

Not at all — Very much

2. To what extent did you feel that you wanted to explore the level and learn more about it?

Not at all — Very much

3. How much do you feel you learned about ancient Mesopotamia from playing the level?

Nothing — A lot

4. Would you say that playing the level has increased your interest in ancient Mesopotamian history?

Not at all — Very much

5. What rating, from 1 to 10, would you give the **navigation** in the level you just played?

1 2 3 4 5 6 7 8 9 10

6. What rating, from 1 to 10, would you give the **sound** in the level you just played?

1 2 3 4 5 6 7 8 9 10

7. What rating, from 1 to 10, would you give the **text** in the level you just played?

1 2 3 4 5 6 7 8 9 10

8. What rating, from 1 to 10, would you give the **interactions** in the level you just played?

1 2 3 4 5 6 7 8 9 10

9. What rating, from 1 to 10, would you give the **aesthetics** in the level you just played?

1 2 3 4 5 6 7 8 9 10

10. What rating, from 1 to 10, would you give the **locations** in the level you just played?

1 2 3 4 5 6 7 8 9 10

11. What rating, from 1 to 10, would you give the **characters** in the level you just played?

1 2 3 4 5 6 7 8 9 10

12. On a rating from 1 to 10, how **engaging** was the level you just played?

1 2 3 4 5 6 7 8 9 10

PRESENCE

Rate the following sentences:

13. I had a sense of "being there" in Uruk

Not at all — Very much

14. There were times during the experience when Uruk was the reality for me

At no time — Almost all the time

15. Uruk seems to me to be more like…

Images that I saw — Somewhere that I visited

16. I had a stronger sense of…

Being in the lab — Being in Uruk

17. Consider your memory of being in Uruk. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of Uruk, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements.

Not at all similar — Very similar

18. During the time of the experience, did you think to yourself that you were actually in Uruk?

Not at all — Very much

ANCIENT MESOPOTAMIA TEST QUESTIONS

Following is a set of questions to test your knowledge of ancient Mesopotamia, specifically the ancient Mesopotamian city of Uruk, around the time of 3000 BC. Don't worry if you don't know the answers, simply mark "don't know". Try not to guess answers you don't know.

19. How do archaeologists know of the widespread use of baskets in ancient Mesopotamia?

______________________________ ☐ Don't know

20. True or false, by 3000 BC the dominant language spoken in the city of Uruk was Akkadian?

☐ True ☐ False ☐ Don't know

21. True or false, according to the Epic of Gilgamesh, Gilgamesh was once the king of the Mesopotamian city of Uruk?

☐ True ☐ False ☐ Don't know

22. Aside from wheat and barley, why was sesame also an important crop throughout ancient Mesopotamia?

______________________________ ☐ Don't know

23. True or false, carved stone cylinders were rolled across clay tablets for decorative purposes?

☐ True ☐ False ☐ Don't know

24. True or false, Mesopotamians used leather made from sheep and goat skin?

☐ True ☐ False ☐ Don't know

25. What is the name of the system used by Mesopotamian farmers to bring water from rivers to the fields?

______________________________ ☐ Don't know

26. Why might people have slept on their roofs during summer in ancient Mesopotamia?

______________________________ ☐ Don't know

27. What are the main two rivers that flow through Mesopotamia?

______________________________ ☐ Don't know

______________________________ ☐ Don't know

28. What is an "ugula" in Mesopotamian society?

____________________________ ☐ Don't know

29. Name a reason why rivers were important to life in the ancient city of Uruk.

____________________________ ☐ Don't know

30. What was the primary material used for writing on in ancient Mesopotamia?

____________________________ ☐ Don't know

31. True or false, pastoral nomads would visit Mesopotamian cities to trade goods?

☐ True ☐ False ☐ Don't know

32. True or false, throughout ancient Mesopotamia, writing first developed as a book-keeping tool for recording wages and the flow of goods?

☐ True ☐ False ☐ Don't know

33. True or false, most marsh dwellers living outside the ancient city of Uruk lived in houses constructed from reeds?

☐ True ☐ False ☐ Don't know

34. In which millennium did writing first appear in Mesopotamia?

____________________________ ☐ Don't know

35. True or false, in Uruk around 3000 BC, many workers would specialise solely in a craft, such as pottery or textiles?

☐ True ☐ False ☐ Don't know

36. True or false, by 3000 BC, horses were an important animal in Mesopotamian society?

☐ True ☐ False ☐ Don't know

37. True or false, in the ancient city of Uruk, most scribal students were boys?

☐ True ☐ False ☐ Don't know

38. True or false, all children throughout Mesopotamia would learn to read and write?

☐ True ☐ False ☐ Don't know

39. True or false, the rivers of Mesopotamia would flood on a seasonal basis?

☐ True ☐ False ☐ Don't know

40. True or false, in the city of Uruk around 3000 BC, when farmers produced a surplus it would be appropriated by the state?

☐ True ☐ False ☐ Don't know

41. What building was situated at the top of a Mesopotamian ziggurat?

____________________________ ☐ Don't know

42. What name is given to Mesopotamian temples divided into three sections?

____________________________ ☐ Don't know

End of Post-Game Questionnaire

5. Interview Script

The following form is the script used for conducting the semi-structured interview with participants after completing the game for the constrained environment experiment:

Script:

I want you to think back to the level you just played. Can you briefly describe to me the experience that you had? What did you do?

Notes:

Do they spontaneously refer to it as a place or physical location they visited?

☐ Yes

Can you briefly describe the places that you visited while playing?

Notes:

How did you find it navigating and exploring those places?

Notes:

☐ No

Do you think of the level you played as being a place that you visited? What makes you feel that way?

Notes:

How did you find it navigating and exploring the different parts of the level?

Notes:

When you were playing, how immersed in the world did you feel? Why?

Notes:

Did you feel that you wanted to collect all of the infonodes?

Notes:

What were your favourite aspects of the game you played?

Notes:

What were your least favourite aspects?

Notes:

Finally, do you have any other comments or anything else you'd like to share?

Notes:

6. Post-Experiment Email

The following form is the email sent to participants after completing the constrained environment experiment:

Post-Intervention Information Email
Re: Mesopotamian History Game Experiment

Dear participant,

Thank you once again for taking part in the Mesopotamian history game experiment, it is very much appreciated and I am sure the data will prove useful.

The purpose of the experiment and the research is to investigate ways of making Mesopotamian history more interesting and engaging for a wider audience. To this end, I wanted to include some additional information, in case the experiment managed to catch your interest and you would like to find out more about this fascinating period of history.

- Here is a YouTube video of the writer John Green talking about ancient Mesopotamia in the series Crash Course World History.
- Here is the Ancient History Encyclopedia page on Mesopotamia.
- Here is the Encyclopaedia Britannica page on ancient Mesopotamian history.
- Here you can find the Wikipedia articles on the history and writing of ancient Mesopotamia.
- The British Museum in London contains extensive collections of ancient Mesopotamian art, artefacts, and cuneiform tablets.
- The Ashmolean Museum in Oxford contains a section on the ancient Near East, also containing many cuneiform tablets.

As stated in the experiment, there will be a short follow-up section of the experiment, which will be completed online. Please expect to receive instructions by email in 3 months' time. After completing these follow-up steps, you will be eligible to win one of the experiment prizes.

Best regards,
Laurence Hanes

7. Long-Term Questionnaire

The following form is the questionnaire given to participants three months after completing the constrained environment experiment:

Post-Game Long-Term Questionnaire (To be Completed Online)

GAME EXPERIENCE

1. How well do you remember your experience of playing the level?

Not at all | | | | | Very well

2. How well do you think you remember the information you learned, playing the level?

Not at all | | | | | Very well

3. Since participating in the experiment, have you taken any steps to learn more about Mesopotamian history?

☐ Yes ☐ No

If so, what were they? ______________________________

4. Do you plan to take any steps in the future to learn more about Mesopotamian history?

☐ Yes ☐ No

If so, what are they? ______________________________

ANCIENT MESOPOTAMIA TEST QUESTIONS

Following is a set of questions to test your knowledge of ancient Mesopotamia, specifically the ancient Mesopotamian city of Uruk, around the time of 3000 BC. Don't worry if you don't know the answers, simply mark "don't know". Try not to guess answers you don't know.

5. What is an "ugula" in Mesopotamian society?

______________________________ ☐ Don't know

6. What is the name of the system used by Mesopotamian farmers to bring water from rivers to the fields?

______________________________ ☐ Don't know

7. True or false, Mesopotamians used leather made from sheep and goat skin?

☐ True ☐ False ☐ Don't know

8. True or false, most marsh dwellers living outside the ancient city of Uruk lived in houses constructed from reeds?

☐ True ☐ False ☐ Don't know

9. What was the primary material used for writing on in ancient Mesopotamia?

______________________________ ☐ Don't know

10. True or false, according to the Epic of Gilgamesh, Gilgamesh was once the king of the Mesopotamian city of Uruk?

☐ True ☐ False ☐ Don't know

11. How do archaeologists know of the widespread use of baskets in ancient Mesopotamia?

______________________________ ☐ Don't know

12. Why might people have slept on their roofs during summer in ancient Mesopotamia?

______________________________ ☐ Don't know

13. What name is given to Mesopotamian temples divided into three sections?

______________________________ ☐ Don't know

14. True or false, pastoral nomads would visit Mesopotamian cities to trade goods?

☐ True ☐ False ☐ Don't know

15. True or false, in the city of Uruk around 3000 BC, when farmers produced a surplus it would be appropriated by the state?

☐ True ☐ False ☐ Don't know

16. What building was situated at the top of a Mesopotamian ziggurat?

______________________________ ☐ Don't know

17. What are the main two rivers that flow through Mesopotamia?

______________________________ ☐ Don't know

______________________________ ☐ Don't know

18. Name a reason why rivers were important to life in the ancient city of Uruk.

______________________________ ☐ Don't know

19. Aside from wheat and barley, why was sesame also an important crop throughout ancient Mesopotamia?

______________________________ ☐ Don't know

20. In which millennium did writing first appear in Mesopotamia?

______________________________ ☐ Don't know

21. True or false, by 3000 BC, horses were an important animal in Mesopotamian society?

☐ True ☐ False ☐ Don't know

22. True or false, in the ancient city of Uruk, most scribal students were boys?

☐ True ☐ False ☐ Don't know

23. True or false, throughout ancient Mesopotamia, writing first developed as a book-keeping tool for recording wages and the flow of goods?

☐ True ☐ False ☐ Don't know

24. True or false, by 3000 BC the dominant language spoken in the city of Uruk was Akkadian?

☐ True ☐ False ☐ Don't know

25. True or false, carved stone cylinders were rolled across clay tablets for decorative purposes?

☐ True ☐ False ☐ Don't know

26. True or false, in Uruk around 3000 BC, many workers would specialise solely in a craft, such as pottery or textiles?

☐ True ☐ False ☐ Don't know

27. True or false, all children throughout Mesopotamia would learn to read and write?

☐ True ☐ False ☐ Don't know

28. True or false, the rivers of Mesopotamia would flood on a seasonal basis?

☐ True ☐ False ☐ Don't know

End of Post-Game Long-Term Questionnaire

Appendix II Constrained Environment Experiment Participant Characteristics Investigations

1. Effects of Participant Gender

1.1. Introduction

This section gives details of a minor analytical investigation performed to ascertain the nature and extent of any influence of participant gender on the documented results of the experiment comparing 3D and constrained environment implementations of Discover Babylon. For the purposes of this analysis, participants will be grouped only by their declared gender, and not by the experimental group they were assigned to, and hence the version of the game that they played during the experiment.

1.2. Results

The distribution of self-assessed enjoyment of the game for male and female participants is shown in Figure 45. A comparison of these results for the two genders was performed. A Shapiro-Wilk normality test was performed and both the Males, $W(22) = 0.77$, $p < 0.001$, and the Females, $W(12) = 0.82$, $p < 0.05$, were significantly non-normal. Therefore, a Mann-Whitney U test was performed and enjoyment of the level amongst Males differed significantly from Females, $U = 66.00$, $z = -2.56$, $p < 0.05$, $r = -0.44$.

No other significant effects of participant gender on the main experimental results were observed.

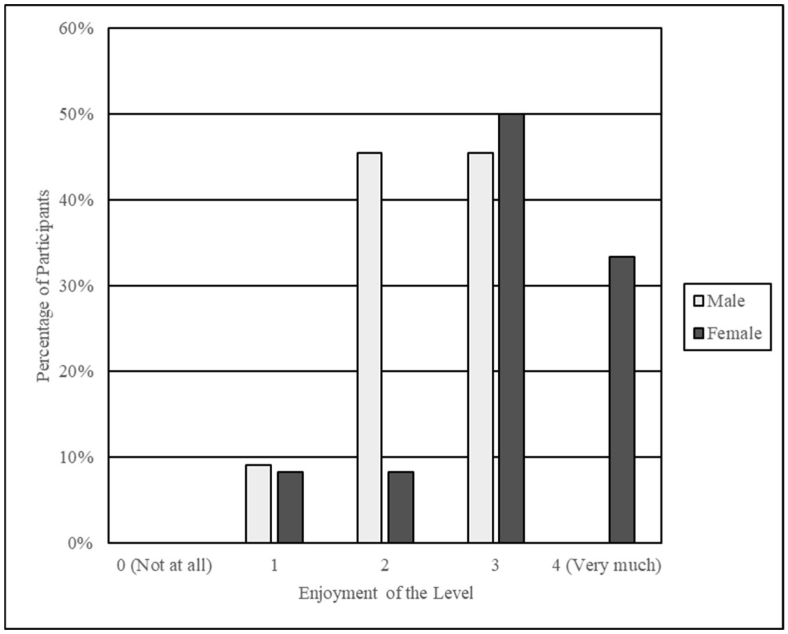


Figure 45. Enjoyment of the game for male and female participants

The distributions of self-assessed enjoyment of the serious game played, split between male and female participants.

1.3. Discussion

It is apparent from these results that female participants enjoyed the game more than males, regardless of the version of the environment they played. Nevertheless, male and female participants had similar results in other categories, such as presence, perception of game quality, post-game interest, and learning. This emphasises the need for careful selection of the target audience, including target gender, and design and evaluation to ensure the game has sufficient appeal for this target audience. An important aspect of this is to ensure that any focus group tests carried out with members of the target audience adequately represent the range of different participant characteristics, including gender.

2. Effects of Participant Educational Discipline

2.1. Introduction

This section gives details of a minor analytical investigation performed to ascertain the nature and extent of any influence of participant educational discipline on the documented results of the experiment comparing 3D and constrained environment implementations of Discover Babylon. For the purposes of this analysis, participants will be grouped only by their declared discipline (categorised as "history", "humanities", or "science and technology"), and not by the experimental group they were assigned to, and hence the version of the game that they played during the experiment.

2.2. Results

The distribution of self-assessed initial familiarity with Assyriology and Mesopotamian history for participants of each education discipline is shown in Figure 46. A comparison of the three groups was performed. A Kruskal-Wallis test was performed and participant initial familiarity with the subject matter is significantly affected by educational discipline, $H(2) = 9.85$, $p < 0.05$. A follow-up Mann Whitney U test was performed to compare history participants against other participants, and familiarity with Mesopotamian history amongst history students did differ significantly from other students, $U = 33.50$, $z = -3.04$, $p < 0.05$, $r = -0.52$.

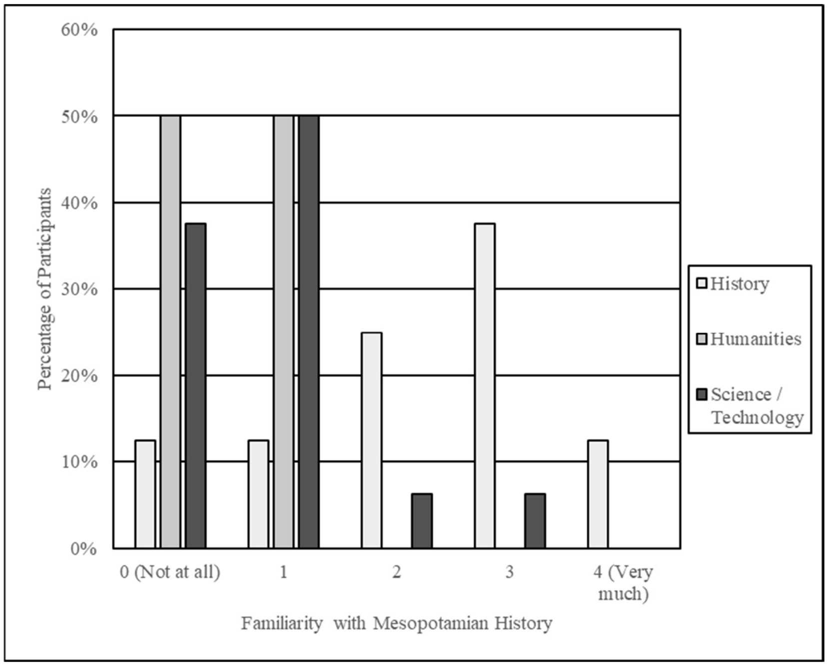


Figure 46. Familiarity with Mesopotamian history for participants from different educational disciplines

The distributions of self-assessed pre-game familiarity with Assyriology and Mesopotamian history, split by participant educational discipline.

Next, the influence of educational discipline on test scores and learning was investigated. The distributions of pre-game test scores for the story questions and the information token questions are shown in Figure 47. Comparisons of the three groups were performed. For the pre-game test scores for the story questions, a Shapiro-Wilk normality test was performed and science/technology students, $W(16) = 0.77$, $p < 0.05$, humanities students, $W(10) = 0.75$, $p < 0.05$, and history students, $W(8) = 0.78$, $p < 0.05$, were all significantly non-normal. Therefore, a Kruskal-Wallis test was performed, and pre-game story score is significantly affected by educational discipline, $H(2) = 11.58$, $p < 0.05$. A follow-up Mann-Whitney U test was performed to test history students against other students and pre-game story score amongst history students did differ significantly from other students, $U = 24.00$, $z = -3.39$, $p < 0.001$, $r = -0.58$. For the pre-game test scores for the information token questions, a Shapiro-Wilk normality test was performed and both science/technology students, $W(16) = 0.77$, $p < 0.05$, and humanities students, $W(10) = 0.75$, $p < 0.05$, were significantly non-normal, but history students, $W(8) = 0.85$, $p > 0.05$, were not. Therefore, a Kruskal-Wallis test was performed, and pre-game information token score is significantly affected by educational discipline, $H(2) = 12.28$, $p < 0.05$. A follow-up Mann-Whitney U test was performed to test history students against other students and pre-game information token score amongst history students did differ significantly from the other students, $U = 22.50$, $z = -3.44$, $p < 0.001$, $r = -0.59$.

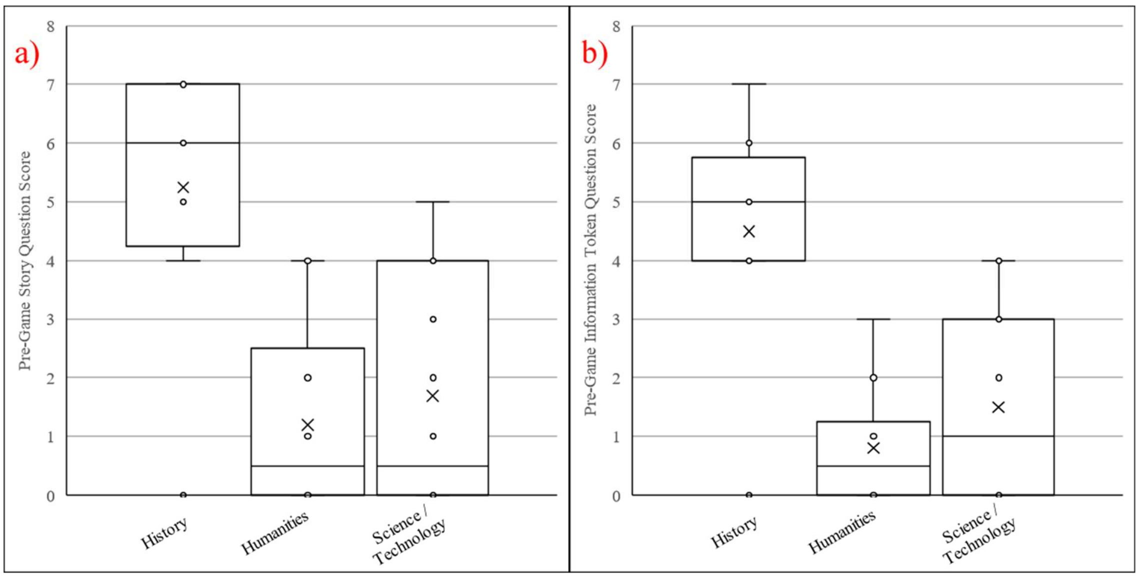


Figure 47. Pre-game test scores for participants from different educational disciplines

a) Box-and-whisker diagrams of pre-game test scores for story questions for participants from history, humanities, and science/technology disciplines; b) box-and-whisker diagrams of pre-game test scores for information token questions for participants from history, humanities, and science/technology disciplines.

The distributions of information conversion rates for the story questions and the information token questions are shown in Figure 48. Comparisons of the three groups were performed. For the conversion rates for the story questions, a Shapiro-Wilk test was performed and neither science/technology students, $W(16) = 0.90$, $p > 0.05$, humanities students, $W(10) = 0.97$, $p > 0.05$, nor history students, $W(8) = 0.91$, $p > 0.05$, were significantly non-normal. Levene's test was performed and the variances for the three educational disciplines are equal, $F(2, 31) =$

0.09, $p > 0.05$. Therefore, a one-way ANOVA was performed and there was no significant effect of educational discipline on story conversion rate, $F(2, 31) = 0.72$, $p > 0.05$, $\omega^2 = -0.02$. Planned comparisons revealed that there was no significant difference between history students and other students, $t(31) = -0.23$, $p > 0.05$, $r = 0.04$, nor between science/technology students and humanities students, $t(31) = 1.19$, $p > 0.05$, $r = 0.21$. For the conversion rates for the information token questions, a Shapiro-Wilk normality test was performed and science/technology students, $w(16) = 0.92$, $p > 0.05$, and humanities students, $W(10) = 0.94$, $p > 0.05$, were not significantly non-normal, but history students, $W(8) = 0.82$, $p < 0.05$, were. Therefore, a Kruskal-Wallis test was performed and information token conversion rate is significantly affected by educational discipline, $H(2) = 8.43$, $p < 0.05$. A follow-up Mann-Whitney U test was performed to compare history students against all other students, and the information token conversion rate amongst history students did differ significantly from the other students, $U = 52.50$, $z = -2.10$, $p < 0.05$, $r = -0.36$.

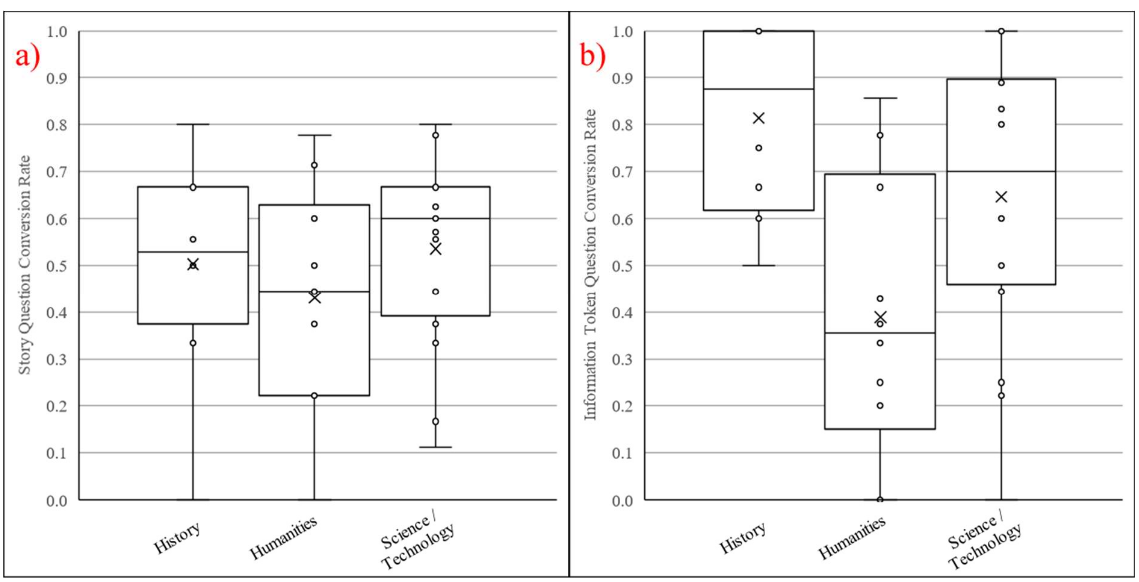


Figure 48. Test conversion rates for participants from different educational disciplines

a) Box-and-whisker diagrams of test conversion rates for story questions for participants from history, humanities, and science/technology disciplines; b) box-and-whisker diagrams of test conversion rates for information token questions for participants from history, humanities, and science/technology disciplines.

No other significant effects of participant educational discipline on the main experimental results were observed.

2.3. Discussion

It is clear from the results that some participants, particularly those from a history educational discipline, entered the experiment with a higher familiarity of the subject matter and a deeper initial level of knowledge, as shown through the pre-game test scores. These participants, however, did not achieve significantly different information conversion rates for the story questions, but did achieve significantly higher conversion rates for the information token questions.

Firstly, this shows the necessity and insight gained by using conversion rates instead of raw test scores, since it can offer an analysis of the learning effectiveness of the serious game, while at the same time accounting for differing levels of initial knowledge among participants. Secondly, it also provides evidence that when the learning content and activities are more closely integrated into the gameplay and game mechanics, as is the case for the game story, the serious game consequently is equally effective at teaching players from different backgrounds with different skills and interests. When the information is presented only through tangential text that is not integrated into the game mechanics, as is the case for the information tokens, the effectiveness of learning is more dependent on the interests and capabilities of the player, especially given the level of effort required to actively read, understand, and internalise the text in the information tokens. This was also observed during the experiment, where some participants (particularly those from a history discipline) would carefully and thoroughly read each information token they found, whereas some participants would dismiss them without even taking the time to read them.

3. Effects of Participant Game-Playing Frequency

3.1. Introduction

This section gives details of a minor analytical investigation performed to ascertain the nature and extent of any influence of the frequency with which participants play video games on the documented results of the experiment comparing 3D and constrained environment implementations of Discover Babylon. For the purposes of this analysis, participants will be grouped only by their self-assessed frequency of playing games ("not very often", "fairly often", and "very often"), and not by the experimental group they were assigned to, and hence the version of the game that they played during the experiment.

3.2. Results

The distributions of mean game scores for participants of differing levels of game-playing frequency are shown in Figure 49. A comparison of the three groups were performed. A Shapiro-Wilk normality test was performed and neither not-often players, $W(9) = 0.97$, $p > 0.05$, fairly-often players, $W(16) = 0.97$, $p > 0.05$, nor very-often players, $W(9) = 0.95$, $p > 0.05$, were significantly non-normal. Levene's test was performed and the variances for the three game-playing frequencies are equal, $F(2, 31) = 0.24$, $p > 0.05$. Therefore, a one-way ANOVA was performed and there was a significant effect of game-playing frequency on mean game score, $F(2, 31) = 4.16$, $p < 0.05$, $\omega^2 = 0.16$. Planned comparisons revealed that there was a significant difference between not-often players and other participants, $t(31) = 2.88$, $p < 0.05$, $r = 0.46$, but none between fairly-often players and very-often players, $t(31) = 0.61$, $p > 0.05$, $r = 0.11$.

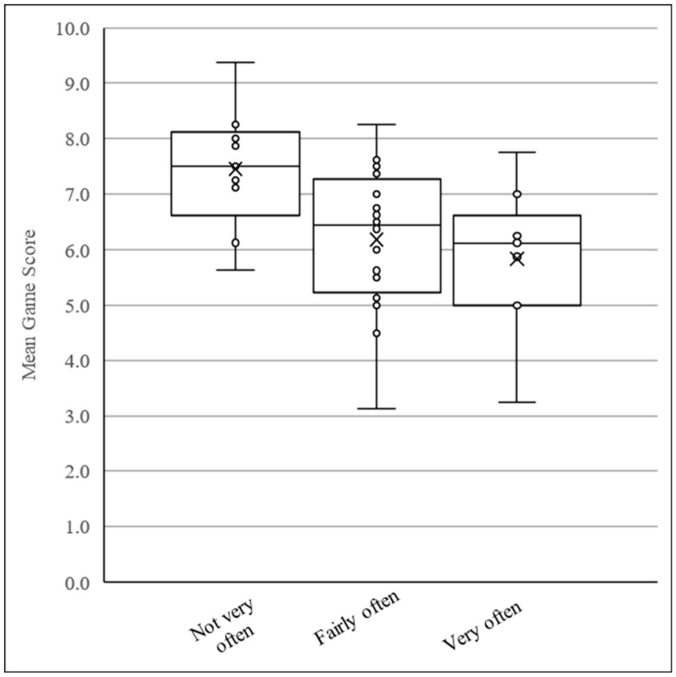


Figure 49. Mean game scores for different participant frequencies of playing video games

Box-and-whisker diagrams of mean game score results, for all experimental participants, split by their self-assessed frequency of playing video games.

The distributions of information conversion rates for the story questions and the information token questions are shown in Figure 50. Comparisons of the three groups were performed. For the conversion rates for the story questions, a Shapiro-Wilk test was performed and neither not-often players, $W(9) = 0.92$, $p > 0.05$, nor very-often players, $W(9) = 0.86$, $p > 0.05$, were significantly non-normal, but fairly-often players, $W(16) = 0.85$, $p < 0.05$, were. Therefore, a Kruskal-Wallis test was performed, and story conversion rate is significantly affected by game-playing frequency, $H(2) = 8.74$, $p < 0.05$. A follow-up Mann Whitney U test was performed to compare not-often players with the other participants, and story conversion rate amongst not-often players did differ significantly from other participants, $U = 39.00$, $z = -2.88$, $p < 0.05$, $r = -0.49$. For the conversion rates for the information token questions, a Shapiro-Wilk normality test was performed and neither not-often players, $W(9) = 0.90$, $p > 0.05$, fairly-often players, $W(16) = 0.90$, $p > 0.05$, nor very-often players, $W(9) = 0.91$, $p > 0.05$, were significantly non-normal. Levene's test was performed and the variances for the three game-playing frequencies are equal, $F(2, 31) = 0.49$, $p > 0.05$. Therefore, a one-way ANOVA was performed and there was a significant effect of game-playing frequency on information token conversion rate, $F(2, 31) = 9.94$, $p < 0.001$, $\omega^2 = 0.34$. Planned comparisons revealed that there was a significant difference between not-often players and other participants, $t(31) = -4.28$, $p < 0.001$, $r = 0.61$, but none between fairly-often players and very-often players, $t(31) = 0.61$, $p > 0.05$, $r = 0.11$.

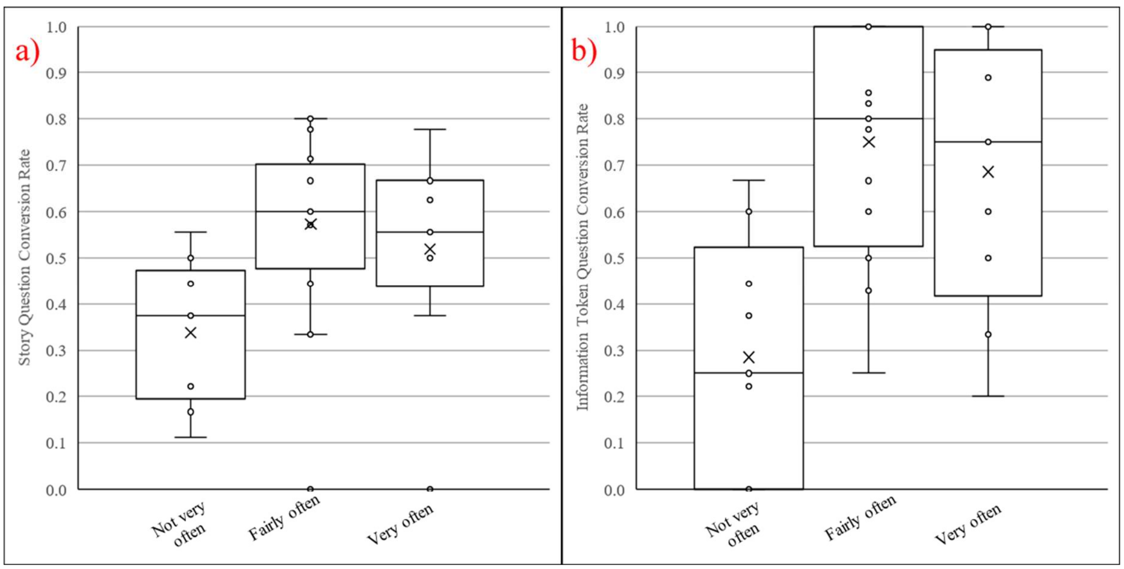


Figure 50. Conversion rates for story and information token questions, split by participant game-playing frequency

a) Box-and-whisker diagrams of Mesopotamian history test conversion rates for story questions, for all experimental participants, split by their self-assessed frequency of playing video games; b) box-and-whisker diagrams of Mesopotamian history test conversion rates for information token questions, for all experimental participants, split by their self-assessed frequency of playing video games.

No other significant effects of participant game-playing frequency on the main experimental results were observed.

3.3. Discussion

The results showed that participants who play video games less often, who might be labelled as "casual" players, liked the game significantly more. This could perhaps be because their expectations of video games, including their mechanics, graphics, interactivity, and design, are lower. However, the participants who play games more frequently, who might be labelled as "core" players, liked the game less. Following the same logic, this could have been because such players have higher expectations of games, and so were more critical of the game that they played during the experiment.

Participants who played less frequently also had significantly lower conversion rates, both for the story and information token questions. A possible reason for this may have been that for more "casual" players, the game mechanics (with their relatively complex requirements of the player) created more cognitive load, allowing less capacity for engagement with the learning material and activities. Whereas, for more "core" players who were already more familiar with these types of game systems and mechanics, they created less cognitive load, which left more capacity to engage with the learning material and activities.

Both of these sets of results stress the importance of clearly defining the target audience of the serious games for heritage, including their familiarity with and frequency of playing video games, which will necessarily have a significant effect on the design of the serious game, its systems, mechanics, and learning activities. As other authors have noted (Bellotti, Berta and Gloria, 2010; Catalano, Luccini and Mortara, 2014; Huang and Tettegah, 2014), the serious game should minimise the cognitive load of interacting with its mechanics, however, as seen here, this cognitive load is actually dependent on the player's level of experience with video games. This therefore reinforces the point that designers of serious games must carefully consider their target audience, including their level of experience with video games.

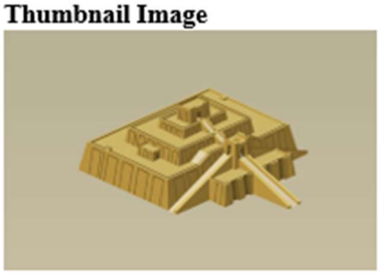
Appendix III Assyriology Serious Game User Test Documents

1. Newgrounds Website Game Posting

The following entry gives the details used to advertise the Assyriology serious game prototype for the user test on the Newgrounds flash hosting website.

Name
Age of the Ziggurats

Thumbnail Image



Short Description
Travel back to ancient Mesopotamia and build a Ziggurat, a colossal brick pyramid, to please the King.

Long Description
Take on the challenge of the Age of the Ziggurats!

Take on the role of the governor of a city in ancient Mesopotamia, who must build a Ziggurat to please the King. Ziggurats are huge stepped pyramids, built by ancient civilizations across the Middle East. They are made from millions upon millions of bricks, for reasons we are still not sure of today. Take up the challenge, complete mini-games, and command your workers to build you a Ziggurat, and discover the mysteries for yourself.

Good luck!

Genre
Strategy – Other

Tags
Ancient; Ziggurat; Construction; Mesopotamia

2. User Test Participant Information Sheet

The following form is the participant information sheet used in the user test for the Assyriology serious game prototype.

Participant Information and Consent Form for Project Entitled:

Educational Games for Ancient Mesopotamian History

This project is formed of an in-the-field experiment and questionnaire looking into Educational Game Design as part of the PhD titled "Presenting Assyriology through Serious Games for Heritage" being carried out in the Department of Electronic, Electrical and Systems Engineering in the University of Birmingham.

The aim of the experiment is to investigate how the design of educational games affects players' enjoyment and their desire to learn more about the subject matter.

The game you will play contains in-game data tracking, which will record basic in-game events as well as the time and date when they occur.

Confidentiality/anonymity and data security

Your data will be treated as confidential and anonymous, as there will be no unique identifiers connecting you to your data. For this experiment, data to be collected will be age and gender. No other personal data is required (no names, ethnicity, etc.).

The results of the experiment will be stored electronically on secure University of Birmingham servers.

If the results prove interesting and noteworthy, then we may decide to produce a paper for publication in a journal or a conference.

Due to your data being anonymous and not uniquely identifiable, withdrawal of your data from this study will not be possible. Therefore, if you are in any doubt about whether you wish for your data to be collected in this study, you are advised not to take part.

Statement of Consent

Fair Processing Statement

This information is being collected as an in-the-field experiment and questionnaire looking into Educational Game Design as part of the PhD titled "Presenting Assyriology through Serious Games for Heritage" being carried out in the School of Electronic, Electrical and Systems Engineering in the University of Birmingham.

The information which you supply and that which may be collected as part of the research project will be entered into a database and will only be accessed by authorised personnel involved in the project. The information will be retained by the University of Birmingham and will be used for the purpose of teaching and research. It may form part of a publication in a technical journal or other forum.

By supplying this information you are consenting to the University storing your information for the purposes stated above. The information will be processed by the University of Birmingham in accordance with the provisions of the Data Protection Act 2018. No identifiable personal data will be published.

By continuing with this game, you agree that:

- You confirm that you have read and understand the participant information sheet for this study. You have had the opportunity to ask questions if necessary and have had these answered satisfactorily.
- You understand that your data will be anonymous and not uniquely identifiable, therefore withdrawal of your data from the study will not be possible.
- You understand that your personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 2018.
- Based upon the above, you agree to take part in this study.

Contact details

If you would like any more information or feedback about this experiment, you are free to contact the research coordinators by the emails shown below.

Laurence Hanes (LXH519@student.bham.ac.uk) – **LEAD EXPERIMENTER**
Robert Stone (R.J.Stone@bham.ac.uk)

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