Chapter 3
A User Study of Virtual Reality for Visualizing Digitized Canadian Cultural Objects

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EXECUTIVE SUMMARY

Algoma University holds an important collection of Canadian objects from the Anishinaabe culture dating from 1880. Some of those objects have been on display in the university's library, but most of them still remain stored in the university's archive, limiting opportunities to use them in teaching and learning activities. This chapter describes a research project focusing on digitizing and visualizing cultural artifacts using virtual reality (VR) technology, with the aim of supporting learning of Canadian heritage in cross-cultural courses. The chapter shows technical aspects of the objects' 3D digitization process and goes on to explain a user study with students watching a 3D model displayed on a low-cost VR headset. Results from the study show that visualization of the 3D model on the VR headset was effective, efficient, and satisfactory enough to use, motivating students to keep using it in further sessions. Technology integration of VR in educational settings is also analyzed and discussed.

INTRODUCTION

The digital preservation and dissemination of cultural heritage have been greatly improved over the past two decades, due to the development of technologies such as web pages, three-dimensional (3D) digitization devices, specialized 3D graphics modelling and visualization software, among other techniques (Bentkowska-Kafel & MacDonald, 2018). The web has allowed better ways of cataloging, documenting,

DOI: 10.4018/978-1-5225-5912-2.ch003

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displaying and accessing cultural information. Using innovations in 3D digitization with accurate sensors allow for registering and capturing more accurate details of cultural objects, including their 3D imaging and modelling (Tsirliganis et al., 2004), and the resulting 3D graphical models can be easily displayed and consulted on websites. More recently, virtual reality (VR) technology has been proposed and researched for enhancing visualization and interaction with 3D graphical models of cultural objects (Ch'ng, Cai & Thwaites, 2018). The premise of VR is to support user's immersion (the person's perception of being physically present in a 3D virtual environment) and to use most of his/her human senses to manipulate virtual objects and perceive multisensory information from a virtual environment (Burdea & Coiffet, 2003). In VR, users generally don a VR headset that greatly facilitates visual immersion, and may use other technologies such as specialized controllers for interacting with the virtual environment (Sherman & Craig, 2002). Immersion in VR is very important for supporting engagement and motivation of users, which can also provide an enhanced learning experience (Gaitatzes, Christopoulos & Rousso, 2001). Other visualization technologies have been researched and applied in the presentation of cultural heritage such as augmented reality, where digital information such as computer graphics are superimposed on video recording from a real-world environment in real time (e.g., Pedersen et al., 2017). A detailed comparison of augmented and virtual reality technologies for cultural heritage is described by Bekele et al. (2018). However, this chapter deals with the use of VR for visualizing digitized cultural objects.

Motivations for conducting digital cultural heritage preservation include: supporting dissemination of digital media collections through websites and virtual museums, ensuring that appearance and shape of cultural objects are not damaged or lost due to natural or human-made causes or accidents, making replicas, identifying art forgery, helping analyze cultural objects (Gomes, Bellon & Silva, 2014), digital restoration and making digital archives of 3D models (Pieraccini et al., 2001) and using digitized cultural objects for learning and teaching purposes (Garcia-Ruiz, Santana-Mancilla & Gaytan-Lugo, 2017). In addition, digital heritage preservation has been used for promoting the inclusion of indigenous knowledge (Kapuire et al., 2017).

The objective of this book chapter is to describe the researchers' process of 3D digitizing Canadian cultural objects belonging to a collection from Algoma University, as part of a research project funded by Algoma University Research Fund (AURF). The chapter also explains the application of the generated 3D models in educational settings, such as Algoma University's library and in classrooms, for learning and teaching purposes. The chapter goes on to describe initial user studies, namely usability and technology acceptance studies with a 3D digital model digitized in our project, and played on a virtual reality headset in a classroom. The chapter also discusses lessons learned on the 3D digitization process and the use of virtual reality in the classroom for digital heritage learning.

BACKGROUND

The literature shows many examples and techniques for the digitization of objects, buildings and archaeological sites in 3D (Portales et al., 2017). There are a number of digital acquisition methods for capturing cultural heritage 3D data to carry out 3D reconstruction, which is the capturing of 3D digital information of a real object and constructing the object's digital shape and appearance (Gomes, Bellon & Silva, 2014). 3D digitizing methods include:

- **Digital Photogrammetry:** It is a technique for acquiring digital photographs and geometric measurements from real-world objects, buildings or sites, generating 2D and 3D graphical models based on the photographs taken with one or more digital cameras and using specialized software algorithms (Linder, 2009). Although accurate, this technique mostly takes a long time because many photographs are needed to generate an accurate 3D model (Remondino & El-Hakim, 2006).
- **Laser Scanning Techniques:** They are based on a system composed of a moving laser source emitting a laser light beam, and an optical sensor that detects the line or pattern of the laser beam projected on the cultural object. Some systems can also acquire surface color (texture) from the digitized objects. This technique generates the digitized object's geometry by applying triangulation algorithms. One advantage of laser scanners is their high accuracy (Pavlidis et al., 2007), but their cost can be high.
- **Contact Digitizing:** This technique utilizes a robotic arm with a sensor in the form of a probe or tip that is manually positioned around the object to be digitized touching its surface, and a software tool is recording its 3D position in space, generating a cloud of points which later will form a 3D model. This method has sub-millimeter accuracy but it is time consuming and it may damage the object's surface (Gomes, Bellon & Silva, 2014).
- **Shape From Structured Light:** This system projects a set of light patterns onto the object to be digitized and an optical sensor detects the distortions of the patterns formed over the object's surface. An example of this system is the Microsoft Kinect (™) sensor, a video game console motion sensor that uses an infrared pattern and acquire surface colors at a range of 30 images per second, although at low resolution. However, this technique is sensitive to the type of ambient illumination (Gomes, Bellon & Silva, 2014).

It is important to note that in some digital heritage projects both digital photogrammetry and laser scanning technologies have been successfully combined, using data fusion for digitizing historical sites and buildings, such as the work described by Guarnieri, Remondino and Vettore (2006) and Munumer & Lerma (2015).

The digitization of cultural objects in 3D has been conducted for some decades. One of the most cited works is the Digital Michelangelo Project, summarizing how a team from Stanford University digitized a number of sculptures from the Renaissance artist Michelangelo (Levoy et al., 2000), using high-end 3D scanners with a resolution of 0.125mm, digitizing the sculptures in color. Researchers found that digitizing objects with shiny and polished surfaces were one of the most challenging tasks. Moreover, The National Research Council of Canada has conducted extensive research and development on 3D scanning techniques and has digitized Canadian cultural objects for a number of years (Corcoran et al., 2002). Other cultural heritage and research institutions such as the Smithsonian Institution in the U.S. are digitizing cultural objects to make their objects' collections more easily accessible to students, researchers and scholars (Jones & Christal, 2002).

Digitizing cultural objects is not trivial, since special care must be exercised when manipulating the objects due to their fragility, and many of them have an intricate surface, which can be difficult to digitize. In addition, nearly all of the generated 3D model files are very large with millions of polygons. Efficient techniques are needed for improving the 3D object digitization and visualization (Santos et al., 2014). Once digitized, the 3D digital models can be shown on a web page and used on VR applications, supporting their analysis (Santos et al., 2014), leveraging on user's engagement, motivation, and immersion, among other characteristics that VR offers (Freina & Ott, 2015). 3D models can also be displayed along with textual or narrated descriptions of the digitized artifacts explaining how an ancient culture used the digitized object (Bustillo et al., 2015). Over the past two decades, many researchers have explored the use of VR to cultural heritage and archaeology.

As it was explained in the Introduction section, VR has been researched and applied for displaying interactive 3D virtual environments containing digitized cultural heritage sites and objects. A number of VR technologies have been used, which include the following:

- **Cave Automatic Virtual Environment (CAVE) (TM):** A CAVE is a large system where a virtual environment containing digital heritage is projected on at least two walls of the system, with the objective of covering most of the users' field of view. In it, a group of users step close to the projection and generally watch the virtual environment in stereo (a visual technique that enhances 3D projection depth) by wearing LCD (shutter) glasses, and they interact with the environment using a 3D mouse or a similar controller. This is a highly immersive system albeit expensive, taking considerable space and can be difficult to set up (Gaitatzes, Christopoulos & Roussou, 2001).
- **Immersadesk (TM):** It is a 2 x 2 meter back-projection system that can be tilted at an angle between 0 and 90 degrees. This projection can be viewed simultaneously by a group of people and they can visualize the projection in stereo by donning LCD glasses, producing high immersion (Gaitatzes, Christopoulos & Roussou, 2001). However, it is an expensive system.
- **Powerwall:** This VR technology comprises a single large projection of a virtual environment, working as a panoramic screen, where its users generally wear LCD glasses to watch the 3D environment in stereo. In addition, other stereo visualization techniques can be used, such as anaglyphs (people wear glasses with red and blue filters) and polarized glasses (Carrozzino & Bergamasco, 2010). This is a highly immersive application but it takes space and can be expensive.
- Web page or computer's software application where a 3D virtual environment can be displayed on a computer monitor. Some websites allow uploading and displaying 3D models of digitized cultural heritage, such as sketchfab.com, where its users can interact with the virtual environment using a mouse. Sketchfab and other similar websites use the Web Graphics Library (WebGL), allowing the visualization of 3D graphical models on web pages and on smartphones. WebGL also allows the visualization of the 3D model in stereo. Using web pages is a low-cost application, and digital cultural heritage can be easily displayed on a museum, a library or in a school using a stand-alone computer. Although this technology provides good interaction and can show high-resolution 3D models (Potenziani et al., 2015), it provides low immersion when played on a computer monitor without stereo projection.
- **VR Headset (Also Called Head-Mounted Display, or HMD):** It is a head-worn device that fully covers the user's field of view. A 3D virtual environment is projected in stereo inside the headset using custom-made internal screen displays, and in some types of VR headsets they are connected to a computer that generates the virtual environment and processes the user interaction. Some models such as the Oculus Go (TM) works as a self-contained system, not requiring an external computer to work. It is also possible to run a self-contained system by inserting a smartphone into some types of VR headsets and run specialized apps on them. The virtual environment then is displayed in stereo on the smartphone's screen. VR headsets detect the user's motion and is reflected this on the virtual environment by using sensors such as gyroscopes, accelerometers, proximity sensors and magnetometers. VR headset applications are highly immersive (Gonizzi

Barsanti et al., 2015). Recent computing advancements have decreased their cost and increased their efficiency and effectiveness considerably for their use in displaying digital heritage (Garcia-Ruiz, Santana-Mancilla & Gaytan-Lugo, 2017).

One of the first fully-fledged archaeological VR exhibits was developed by Gaitatzes, Christopoulos and Roussou (2001). These researchers set up a CAVE with two large immersive projections (3m x 3m) intended for a small audience, displaying a virtual world depicting reconstructions of the ancient city of Miletus (it is situated by the coast of Asia Minor) and a digital reconstruction of the Temple of Zeus at Olympia, in Greece. Users watched the projection in stereo by wearing LCD (shutter) glasses. The virtual world was interactive, where people navigated through 3D models of ancient temples by using a 3D mouse. In one activity, the VR system allowed users to reconstruct an ancient vase by putting together virtual clay pieces. Researchers found (as in other similar projects) that one of the advantages of providing VR archaeology experiences is that they transport users to other times and places that may be difficult to experience in real life.

More recently, high-end VR headsets such as the Oculus Rift (TM), which requires a powerful personal computer to operate, has been used in studies about digital heritage dissemination. For example, Gonizzi Barsanti et al. (2015) explored the use of the Oculus Rift for displaying a virtual environment containing digitized heritage about Egyptian funeral objects exhibited in the Sforza Castle in Milan, Italy. It contained responsive points of interest to facilitate navigation through the virtual environment and inspecting the digital heritage objects. The researchers also used the Leap Motion (TM), a sensor that detects hand movements in 3D, for tracking user's interaction in the virtual environment. Recent research done by Fernandez-Palacios, Morabito and Remondino (2017) utilized the Oculus Rift VR headset where digitally reconstructed heritage sites with very high resolution are displayed on it, and the Microsoft Kinect sensor was used for capturing the user's interaction with the virtual environment. The researchers point out the importance of VR applied to heritage dissemination such as fragile environments and archaeological sites with forbidden access, where users can virtually inspect their contents.

Fabola, Miller and Fawcett (2015) explored the use of the Google Cardboard (TM), a very low cost and lightweight VR headset that displays a virtual environment in stereo by running a mobile app on a smartphone that is inserted in the headset. This app uses the smartphone's sensors to adjust the viewer's position and orientation in the virtual environment, and the headset has a button that the user presses for selecting an option from a menu and navigate to a point of interest, among other actions. However, the researchers implemented in their app a hands-free interaction technique, where the app has virtual hotspots with associated events that can be triggered when the user looks towards a specific hotspot. Fabola, Miller and Fawcett (2015) developed a digital reconstruction of St. Andrews cathedral in Scotland, working as a tool for disseminating cultural heritage information. Interestingly, multimedia presentation was also presented on the 3D reconstruction, such as videos, image and audio narrations about the cathedral, providing an important context about it. Fabola, Miller and Fawcett (2015) conducted a user study of the VR application with nine people reported that the application had high usability and all the participants perceived it to have high educational value. In addition, all nine participants declared a very high immersive 3D experience. There are other research projects and applications using lightweight VR headsets for displaying digital heritage. For example, the British Museum used the Samsung Gear (TM), another type of VR headset that works with Samsung smartphones, for displaying digital heritage in one of their learning programs intended for family, teens and school visitors of the museum (Rae & Edwards, 2016). In this program, digital heritage with 3D models of artifacts and reconstruction of scenes of the Bronze Age were applied. People who used the VR application at the museum reported positive feedback and were enthusiastic about using this technology.

Casu et al. (2015) developed a VR software tool for supporting learning and teaching of art history and cultural heritage in the classroom, in particular about two digitized Michelangelo's sculptures displayed in a virtual museum. The tool offered two types of graphics rendering: In its High Fidelity Mode, students could visualize the virtual sculptures with more realism but it was computationally expensive. In its Fast Rendering Mode, the virtual sculptures were visualized at the lowest resolution but this avoided unpleasant light reflections unintentionally projected in the virtual museum. In the VR software tool, students could write textual annotations close to the virtual artworks. An early user test running the VR software tool on the Oculus Rift and on Google cardboard VR headsets found that high-school students who used the VR headsets for analyzing the virtual sculptures increased "their motivation in studying the lesson topic, in particular increasing their attention, satisfaction and the perceived relevance of the teaching material" (Casu et al., 2015, p. 83). Other research studies that used Google Cardboard for heritage site dissemination and their use in museums describe positive results (e.g. Sooai et al., 2016).

ORGANIZATION BACKGROUND

Algoma University (AlgomaU) is a teaching-oriented and student-centered educational institution located in Sault Ste. Marie, Ontario, Canada, established in 1965. It currently serves a diverse body of about 1600 regional, international students, and local indigenous students as well. AlgomaU offers professional, liberal arts and sciences degree programs, including cross-cultural courses on indigenous education.

Algoma University's Wishart Library houses an important collection of cultural objects crafted by local indigenous people from the Anishinaabe culture dating back from the 1800s. These objects belong to the Engracia de Jesus Matias Archives and Special Collections. Nearly a hundred small objects have been cataloged online, shown in Artifact collection (2018). Figure 1 shows an example of one cultural object cataloged by the Library.

However, just a very small sample of those objects have been on display at the library's main floor, mainly because of the fragility of some objects, among other reasons. Figure 2 below shows the Library's main hall and some display cases. In the authors' opinions, this may limit students' opportunities to know more about local Canadian culture.

SETTING THE STAGE

Digitizing cultural objects in 3D is not new. One of the most cited works is the Digital Michelangelo Project, summarizing how a team from Stanford University digitized a number of sculptures from the Renaissance artist Michelangelo (Levoy et al., 2000), using high-resolution 3D scanners with a resolution of 0.125mm, digitizing the sculptures in color. Researchers found that digitizing objects with shiny and polished surfaces were one of the most challenging tasks. The National Research Council of Canada has conducted extensive research and development on 3D digitizing techniques and has digitized Canadian cultural objects for a number of years (Corcoran et al., 2002).

Other cultural heritage and research institutions such as the Smithsonian Institution in the U.S. are digitizing cultural objects to make their objects' collections more easily accessible to students, researchers

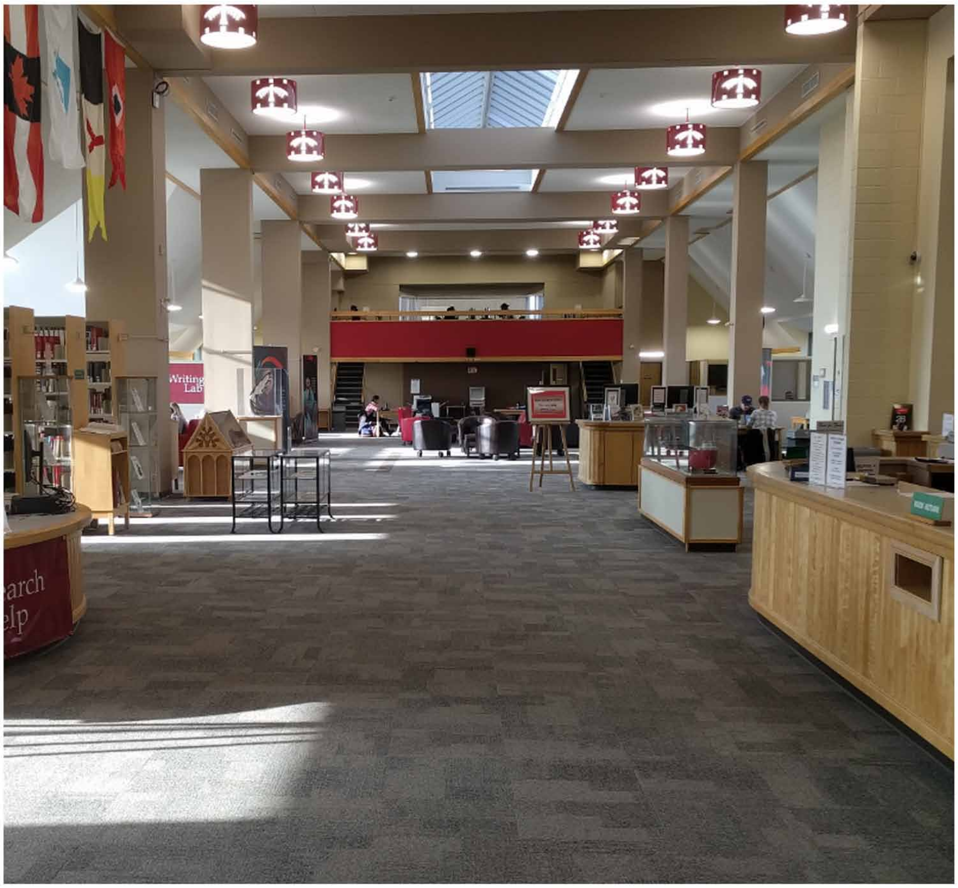
Figure 1. Example of a cultural object stored in the university archives

and scholars (Jones & Christal, 2002). Once digitized, the 3D digital models can be shown on a web page and used on VR applications, supporting their analysis (Santos et al., 2014) leveraging on user's immersion and engagement among other characteristics that VR offers (Freina & Ott, 2015). The 3D model can also be displayed along with a textual or narrated description of the digitized artifact explaining how an ancient culture used the digitized object (Bustillo et al., 2015). However, digitizing cultural objects is not trivial, since special care must be exercised when manipulating the objects due to their fragility, and many of them have an intricate surface, which can be difficult to digitize. In addition, nearly all of the generated 3D model files are very large with millions of polygons. Efficient techniques are needed for improving the 3D object digitization and visualization (Santos et al., 2014).

CASE DESCRIPTION

The authors are currently conducting a research project that focuses on digitizing Canadian cultural objects in 3D and use them in educational applications. Initial work has been originally described in Garcia-Ruiz et al. (2017) and was supported during its first year by the Algoma University Research Fund (AURF). The overarching aim of this project is to use the resulting objects' 3D models in courses where Canadian culture is taught. One objective is to see if the tools, methods and resulting 3D models are technically feasible for educational applications. Another objective is to carry out user studies to test and analyze the usability (ease of use) and technology acceptance of the digitized 3D models displayed on a digital library and a classroom, and using virtual reality (VR) technology such as an easy-to use VR headset.

Figure 2. The newly-renovated Arthur A. Wishart library's main floor



This should improve and support students' learning experience (Virvou and Katsionis, 2008; Zaharias, 2004, 2006), in particular about learning Canadian culture. This also supports the potential educational benefits of engagement and intrinsic motivation with the use of immersive VR (Dalgarno & Lee, 2010).

In this project, usability and technology acceptance of virtual reality technology are analyzed and studied. Usability testing analyzes how easy a computer application's user interface (UI) is to use in terms of quality components such as efficiency, effectiveness and user satisfaction in a specific context of use (Dumas & Redish, 1999; Nielsen, 2012; Rubin & Chisnell, 2008). In this project, the contexts of use were a university classroom, Algoma University's Wishart Library, and its Gaming Technology lab. This is a computer lab used by students who are taking the Bachelor of Computer Science's video game technology specialization.

Technology acceptance is a complement of usability testing. It analyzes how users of technology accept and use a particular in a specific context of use. The Technology Acceptance Model (TAM) version 2 proposes that when users are presented with a new technology, a number of factors determine their decision about when and how they will use it. The TAM version 2 questionnaire (shown in Appendix A) has been used in previous research studies for evaluating VR applications in learning and training settings (e.g., Fang et al., 2014; Fokides, 2017). In addition, the TAM analyzes user's attitudes towards technology use. This is based on two user beliefs:

- **Perceived Usefulness:** "The degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). In our case, "job performance" refers to the users' performance when using our VR system for visualizing and analyzing a digitized cultural object.
- **Perceived Ease of Use:** "The degree to which a person believes that using a particular system would be free from effort" (Davis, 1989, p. 320). This belief is related to usability, which is related to his/her preconceived notion on how easy VR will be to use for watching and interacting with a 3D model of a cultural object.

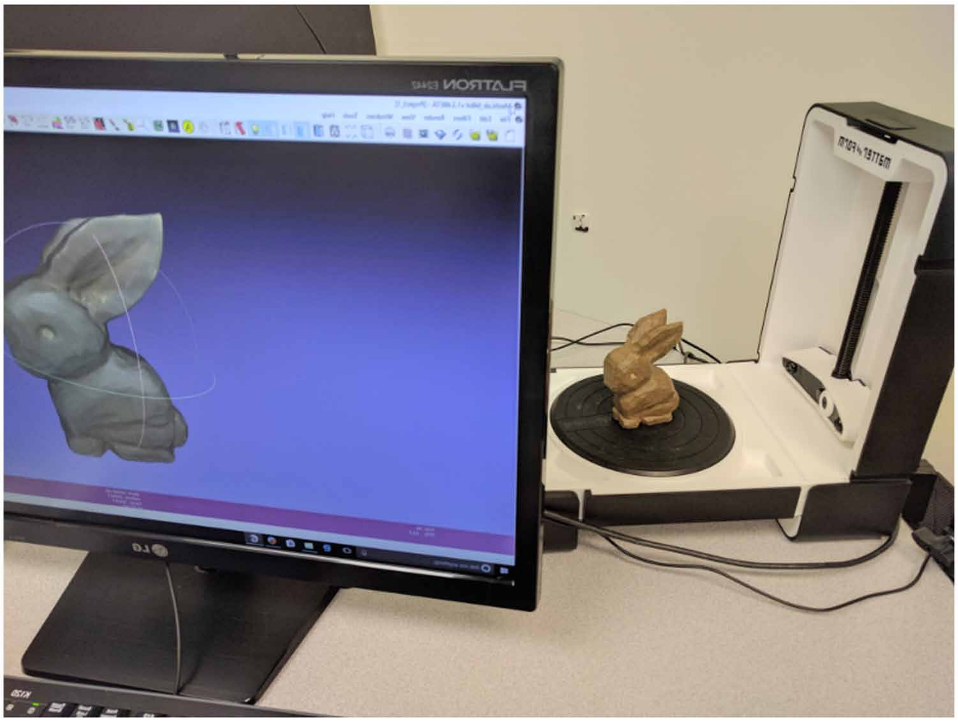
Technology Components

The authors are using in this project a Matter and Form 3D scanner (Matter and Form, 2018) for digitizing cultural objects from AlgomaU's archives. This is an affordable and easy-to-use scanner that captures detail of up to 0.43 mm in RGB color and can digitize objects with a maximum height of 25 cm and width of 18 cm, with a maximum weight of up to 3 kgs, thus it is intended for digitizing small objects. The scanner uses two laser beams to acquire 3D reference points from the object's surface and shape and uses a moving platform to rotate the object to digitize it. Digitizing (scanning) a small object takes about two hours, since it is a quite intensive and accurate process. The objects are digitized twice both in lying and upright positions for acquiring many details in 3D, from many angles. The scanner's companion software was used to merge the two obtained 3D models and their respective textures automatically. The two obtained 3D models were saved in .OBJ format, used by industry-standard computer graphics editors and 3D modelers. The Matter and Form scanner is shown in Figure 3.

The authors connected the 3D scanner to a graphics-enhanced (gaming) laptop computer with 8 GB of RAM and a solid-state hard drive (SSD). He also connected a 24" high-quality computer monitor to the laptop. This helped the 3D model visualization obtained from the digitization (shown in Figure 3). The laptop was running Windows 10 (TM) for running the 3D scanner, and the same laptop also ran Ubuntu Linux distribution, used for revising the obtained 3D models. Using Linux was a matter of preference, since the same software tools used in this project were also downloaded and ran on Windows. The graphics performance on both Linux and Windows appeared to be the same. However, the 3D scanner only offered a software tool and a driver for the Windows operating system.

It is important to note that the 3D scanner did not acquire some of the textures correctly at the time of digitizing an object. Some of them present slight imperfections and small changes in their brightness, due to the intricate objects' shape, shadows and other issues. In order to visualize, review and improve the resulting 3D models from the 3D digitizing process, the research assistants used a software tool called MeshLab (Meshlab, 2018). This tool was very useful for filling holes let by the digitization process in the 3D mesh, among other graphics operations. A student who collaborated in the project was also using Blender (Blender, 2018), another software tool used for manipulating and improving our 3D models. The student also used a powerful image editor called GIMP (GIMP, 2018) for fixing the colors of the 3D models' associated textures. All these software tools are robust, free, open source and easy to use, with a shallow learning curve.

Figure 3. The matter and form 3D scanner used in this project



The project assistants digitized some cultural objects that were used as a proof of concept to test the VR technology used in this project, and one of them was used in our usability and technology acceptance testing sessions. They initially digitized two small wooden carved figures from the University archives, a bunny rabbit (Bunny, 2018) and a dog (Dog, 2018). The first author obtained permission from the Wishart library to use the cultural objects' 3D models and the archive's information posted online in this project.

Once the cultural objects were digitized, revised and improved, the resulting 3D models were uploaded to Sketchfab (Sketchfab, 2018). This is an easy and free-to-use web site for non-commercial applications used to share and show interactive 3D models. Sketchfab has an option to watch the models in stereo (the model is rendered twice, one graphic rendering for each eye). The 3D model is opened on a smartphone's web browser and then the smartphone is inserted into a VR headset such as Google Cardboard (Fabola et al., 2015) and similar low-cost headsets. Models uploaded to Sketchfab can be watched on a web browser from any recent mobile device (e.g. smartphones) or desktop computer that supports the WebGL 3D graphics library. Sketchfab also allows to upload and display the object's textual and metadata description, such as the digitized objects' original measurements. Sketchfab has two options for interacting with the object: "Orbit" and "First Person". When selecting the Orbit option from Sketchfab's menu, users can move the camera (panning) and zooming in or out around the 3D model. In the First Person option, users can look around the object. Both interaction options can be selected and performed using either a computer keyboard, a mouse or swiping on a touch display device such as a smartphone. Currently, however, Sketchfab does not have this capability when users visualize the object in stereo and when the smartphone is inserted into a VR headset. In addition, users can also set up the graphics rendering and lighting from Sketchfab's menu (Sketchfab Controls, 2017).

People can interact with the 3D model visualized in Sketchfab by turning their heads around, thus using the smartphones' accelerometer for looking around the 3D environment. The Sketchfab web page containing the 3D model of the digitized bunny is publicly available at: Digitized bunny (2018). The digitized dog is available from: Digitized dog (2018). Other models uploaded to the Sketchfab website have been successfully used in digital archeology for sharing 3D models of cultural objects that were acquired with 3D scanners (Barrettara, 2013). Sketchfab has also been used for disseminating cultural heritage by institutions such as the British Museum (Lloyd, 2016). Sketchfab has a very easy-to-use user interface (UI), and the website is lightweight enough for using it on almost any recent personal computer or smartphone.

User Study

To analyze the feasibility and potential applications of the proposed educational VR application displaying the obtained 3D models, the authors conducted a user study where five participants tested the usability and the technology acceptance of the Sketchfab models watched on a VR headset. The Sketchfab website was opened on the Chrome web browser from a Google Nexus 5 smartphone, shown in Figure 4. The Nexus 5 provides a resolution of 1920x1080 pixels with a diagonal size of 12.5 centimeters and a clock speed of 2.26 GHz, with a quad core processor. The phone was inserted into an EVO Next VR headset, model no. MIC-VRB03-101. The authors decided to use this particular brand and model of VR headset because it is low cost, comfortable to wear and easy to adjust.

Participants

At the beginning of the study session, participants filled out a demographic questionnaire, shown in Table 1. Five computer science students from Algoma University participated in the study. Their age average was 22 years old (4 males and 1 female). In order to evaluate the overall usability of the VR setting, the authors did not need to test it with many participants. According to Nielsen (2000), just 5 participants will report about 85% of the usability problems of an interactive computer application. None of the participants reported serious vision problems or disabilities. Some of them wore glasses, but they

Figure 4. The VR headset with the smartphone inserted in it

Table 1. Demographics questionnaire

These questions are used to help identify trends in responses. Please remember that your responses will be completely confidential and anonymous. 1. Gender: ______ Male ______ Female 2. Age (to the nearest year): _____ 3. Have you used virtual reality (VR) equipment before (e.g. VR headset)? If yes, which one(s)? ________________________________ ____________________________ 4. Have you taken courses where Canadian culture and/or heritage has been taught in them (Y/N) ? ___ 5. Have you played 3D video games? If yes, for how long have you played video games? _____ 6. What type of player are you (player skills)?: ____ Non-video game player ____ Novice player ____ Occasional player ____ Expert player ____ Frequent/hard core player

decided to remove them before they visualized the 3D model using the VR headset. Those participants reported that not wearing the glasses did not affect the model visualization, since they could successfully adjust the headset lenses.

The authors tested the VR application in three areas: Algoma University's Gaming Technology Laboratory (a computer lab), the Wishart Library, and a classroom. It is important to test the usability and analyze the VR system's technology acceptance in those places because they are natural educational settings, and the authors wanted to know how students will use the VR headset in those places. Thus, the user studies run in this project can be considered as a type of field study. Figure 5 shows a student testing the VR setting in a classroom.

The usability testing methodology applied in this user study was the Concurrent Think Aloud Protocol, or CTAP (Alshammari, Alhadreti & Mayhew, 2015). In the CTAP, usability specialists ask participants to say out loud their opinions and feelings and decisions about using a digital device's UI, while they are interacting with it. The authors consider CTAP as a practical yet powerful methodology for uncovering problems "on the fly", which may hinder learning issues in an educational application with technology. It is particularly suitable with this VR application because students can verbalize VR application's usability problems right away, when those happened, while they are visualizing the 3D model using the VR headset.

After participants completed the study tasks, they filled out the widely-used and reliable System Usability Scale (SUS) questionnaire (Brooke, 1996), shown in Table 2. This questionnaire has been previously applied in a number of studies where virtual reality environments have been evaluated (e.g. Correa et al., 2017, Garcia-Ruiz, Santana-Mancilla & Gaytan-Lugo, 2017). The SUS has ten Likert scales where participants rated each one from 1 ("strongly disagree") to 5 ("strongly agree"). They also filled out the Technology Acceptance Model version 2 (TAM2) questionnaire (Venkatesh & Davis, 2000), shown in Appendix A. The authors have successfully used both questionnaires in previous studies, yielding valuable user feedback (Garcia-Ruiz, Santana-Mancilla & Gaytan-Lugo, 2017).

Figure 5. A student wearing the VR headset

Procedure

Each participant's session lasted about 45 minutes. The participants' tasks were the following:

- Visualize a 3d model of a cultural object digitized in this project, analyzing it from any possible angle, so participants needed to "walk" around the model and turn their heads.
- Identify the type of material and estimate the real size of the digitized object.

The following describes the testing session steps, based on the usability testing steps outlined by Rubin & Chisnell (2008) and in Usability Test (2017):

- **Pre-Test Arrangement:** Prepare everything for the test. Turn the smartphone on, open the Sketchfab website on the smartphone displaying one of the digitized objects' model in 3D. Insert the smartphone in the VR headset. Make sure everything works OK.

Table 2. The SUS questionnaire

1. I think I would like to use this VR application frequently	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
2. I found the VR application unnecessarily complex.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
3. I thought the VR application was easy to use.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
4. I think I would need the support of a technical person to be able to use this VR application.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
5. I found the various functions in this VR application were well integrated.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
6. I thought there was too much inconsistency in this VR application.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
7. I would imagine that most people would learn how to use this VR application very quickly.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
8. I found the VR application very cumbersome to use.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
9. I felt very confident using the VR system.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5
10. I needed to learn a lot of things before I could get going with this VR application.	Strongly Strongly disagree agree 1………2…...…3……….....4………..5

- **Session Introduction:** the authors welcome the participant. They briefly explain the study objective, relevance, the TAP methodology, and the tasks. The participant reads and signs the consent form to participate in this research. The form also summarizes the instructions for the test, including the usability testing and technology acceptance objectives.
- **Testing Tasks:** the participant starts the study by wearing the VR headset and begins performing the tasks for this session, saying out loud his/her opinions, feelings and decisions about the tasks. The authors then take notes on the participant's comments. The testing continues until the all the tasks were competed or the allotted time has elapsed.
- **Post-Test Debriefing and Conclusion:** The authors ask general questions on the test. The participant fills out the SUS and TAM2 questionnaires. Finally, the authors thank the participant.

Table 3. results of the technology acceptance model (TAM2) questionnaire

Participant No.	Likert Scale (Questionnaire Item) Number (1=strongly disagree...7=strongly agree)																									
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L 10	L 11	L 12	L 13	L 14	L 15	L 16	L 17	L 18	L 19	L 20	L 21	L 22	L 23	L 24	L 25	L 26
P1	5	6	3	3	3	3	7	7	7	7	1	1	7	7	7	4	4	4	2	2	5	6	7	5	7	1
P2	7	7	6	6	4	4	7	7	7	7	6	4	7	7	7	4	2	2	2	3	5	6	6	6	6	4
P3	6	6	4	4	5	4	6	7	6	7	4	4	7	4	4	4	4	4	4	5	6	6	6	4	6	4
P4	6	6	5	5	5	5	7	7	7	7	4	4	7	7	7	4	4	4	4	4	6	5	6	6	6	4
P5	6	5	4	5	5	5	6	7	7	7	4	4	7	7	7	4	3	4	4	4	6	6	6	6	6	4
Me-dian:	6	6	4	5	5	5	7	7	7	7	4	4	7	7	7	4	4	4	4	4	6	6	6	6	6	4
Mode:	6	6	4	4	5	4	7	7	7	7	4	4	7	7	7	4	4	4	4	4	6	6	6	6	6	4

RESULTS AND DISCUSSION

Most the participants reported in the CTAP that the EVO VR headset was lightweight and compact. It was easy for them to adjust the lenses' interpupillary and eyeball distances, although two of them reported that the VR headset was a little uncomfortable when sitting on the nose.

According to the results from the TAM2 questionnaire (shown in Table 3) and participants' comments made during the Concurrent Think Aloud (CTAP), it seems that the VR application motivated participants to continue using Sketchfab models displayed on a VR headset in further educational applications. In addition, this study arouses students' curiosity on how an easy-to-use VR application can be used in an educational setting. The 26 Likert scales from the TAM2 questionnaire are enlisted in Appendix A.

According to the results obtained through the participants' responses, the median for items: 3, 6, 11, 12, 16-20 and 26 was four; the median for items: 4 and 5 was five; meanwhile, the median for items: 1, 2 and 21-25 was 6; finally, the median for items: 7-10 and 14-15 was seven. Furthermore, the participants' response with the lowest median was 4,5. The second participant with the highest median was six.

Each of the SUS questionnaires (shown in Table 4) was scored according to Brooke (1996), where a usability value was obtained (a percentile) where 50=very bad usability and 100=excellent usability.

Table 4. Results of the system usability scale (SUS) questionnaire

Participant No.	Likert Scale (Questionnaire Item) Number (1=strongly disagree...5=strongly agree)										
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	SUS Score
P1	4	1	5	2	4	1	5	1	5	1	92.5
P2	5	1	5	1	4	2	5	1	4	1	92.5
P3	4	1	4	1	3	2	4	1	4	1	82.5
P4	4	1	4	1	5	2	4	1	4	1	87.5
P5	4	2	4	1	4	2	4	1	4	1	82.5
Median and mode	4	1	4	1	4	2	4	1	4	1	

The average of the results from the five SUS questionnaires was 87.7. This score is in the 80th percentile, meaning that the VR application's usability was very high (Sauro, 2011). Individual results from the SUS' Likert scales are very favorable, although do not have excellent usability, as most of the participants rated scales 1,3,5,7 and 9 (positive usability outcomes) with a value of 4.

During the CTAP, participants were asked to estimate the real size of the digitized object visualized on the VR headset (they did not know the real size before the test). Most of the participants answered that the object's size was really big, of about one meter in height. Just one participant could correctly estimate the object's size. He mentioned in the CTAP that he was using the checkered floor from the VR environment as a reference. The real size of the digitized object is small, which is 3.2 x 7.7 x 10.2 cm. In further uses of the VR application, the authors will include reference points or other virtual objects that will help estimate the real size of digitized objects more accurately. Participants were also asked about the material the real object was made of. Three of them correctly answered that the object was made of wood. The authors think that it was due in part because of the smartphone's brightness control adjustment. Participants did not report serious usability problems. All the participants noticed a very small lag on the 3D model visualization, but it was not a big cause of concern. This can be remediated in further VR applications by using a faster smartphone and with better graphics capabilities. Each testing session was short, making it difficult to see if the VR application was engaging enough in the long term. It seems that participants experienced a "novelty effect" when they used VR technology. This is consistent with other similar studies (e.g. Merchant et al., 2014).

SOLUTIONS AND RECOMMENDATIONS

The following is a list of recommendations on the 3D digitization process and VR usage in educational settings. They are based on the authors' usability and technology acceptance study and their digitization process:

- Before starting digitizing objects in 3D you must calibrate the computer monitor(s), so your monitor(s) will show colors more closely to the digitized objects.
- The authors found that using dimmed LED lights with an opaque white filter was the best option for illuminating the digitized objects with the Matter and Form scanner. One LED light placed in front of the scanner and one in the back helped to reduce casting shadows around the object. Shadows do affect the digitization quality, and the light filters helped to decrease the object's surface shininess. The LED lights are shown in Figure 6. Compact fluorescent (CFL) light bulbs and fluorescent lights from the office ceiling were also tried with mixed and often undesirable results.
- Do not place heavy objects on the Matter and Form 3D scanner's rotating platform. If you do that you could break some of its mechanical components. That scanner can hold a weight of up to 3Kg.
- Conduct user testing of the VR equipment and its software application. Use standard usability testing and technology acceptance methodologies. The authors found in this and other studies (e.g. Garcia-Ruiz et al., 2017) that the CTAP is a very useful and practical methodology for testing VR applications, as well as using the TAM2 and SUS questionnaires.
- Run a dry test of the equipment and software before the main user study starts. Set up everything and try out the VR headset and 3D model visualizations with 1 or 2 people, to see if everything works and maybe make some final adjustments to the VR headset or the smartphone.

Figure 6. LED lights configuration

- As with most virtual reality equipment, be aware that watching the 3D models on the VR headset may cause seizures or dizziness in susceptible people. You must ask users first if it is OK if they can visualize the 3D model on the VR headset.
- Clean the smartphone screen with a special cloth prior to its usage with the VR headset. Fingerprints or dust on the smartphone's screen may make the VR visualization somewhat blurred.
- Do not forget to explain users how to adjust the lenses from the VR headset. This is a very important step, otherwise the VR application may look either blurred or distorted. Many VR headsets allow the adjustment of the lenses' interpupillary distance, which is the distance between the user's eyeballs, and the distance between the lenses and the eyeballs.
- There are actions that can be used to overcome the challenge of technology integration of VR in the classroom: having more savvy instructors who can help up other instructors (budding up), and holding hands-on information workshops with instructors, working administration staff and instructors collaborating in this endeavor (Kirkwood, 2015).

CONCLUSION

This chapter described an overview of digital preservation of cultural heritage objects in virtual reality and its importance. There are sufficient motivations to do so, including supporting dissemination of digital media collections through websites and virtual museums, ensuring that appearance and shape of cultural objects are not damaged or lost due to natural or human-made causes or accidents, identifying art forgery, and using digitized cultural objects for learning and teaching purposes. In addition, the chapter explained our research project concerning digitization of cultural objects pertaining to Algoma University, Canada, its 3D digitization process, and the visualization of digitized 3D models using VR technology. The objective of digitizing these objects is to use the obtained 3D models for supporting teaching and learning Canadian culture and heritage. The chapter also reported a user study (usability testing and technology acceptance) about interacting with the digital objects in VR. the chapter explained technical and logistic problems found in the digitization process and the use of the digitized objects. A valuable part of this chapter is the lessons learned about the 3D digitization process.

Results from the researchers' user studies indicate that low-cost VR technology can be useful and effective for supporting visualization of digital heritage objects, in particular about its use in educational settings such as in the classroom. It can become an important didactic tool which is easy to set up and use. The latter allowed us to determine the positive students' acceptance of VR technology for learning purposes. The high usability of the web site used in our study (Sketchfab) yielded high potential for further use in learning and teaching about cultural heritage. This user study also suggests that the use of the low-cost VR headset was an effective way of analyzing the graphical 3D models of cultural objects. This is in line with our previous research on educational VR (Garcia-Ruiz, Santana-Mancilla & Gaytan-Lugo, 2017).

REFERENCES

Alshammari, T., Alhadreti, O., & Mayhew, P. (2015). When to ask participants to think aloud: A comparative study of concurrent and retrospective think-aloud methods. *International Journal of Human-Computer Interaction*, *6*(3), 48–64.

Artifact Collection. (2018). Retrieved from http://archives.algomau.ca/main/node/20942

Barrettara, M. (2013). New methods for sharing and exhibiting 3D archaeology. *The Posthole*, *31*, 8–13.

Bekele, M. K., Pierdicca, R., Frontoni, E., Malinverni, E. S., & Gain, J. (2018). A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage. *Journal on Computing and Cultural Heritage*, *11*(2), 7. doi:10.1145/3145534

Bentkowska-Kafel, A., & MacDonald, L. (Eds.). (2018). *Digital techniques for documenting and preserving cultural heritage*. Kalamazoo, MI: Arc Humanities Press.

Blender. (2018). Retrieved from: https://www.blender.org/

Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability Evaluation in Industry, 189*(194): 4-7.

Bruno, F., Bruno, S., De Sensi, G., Luchi, M. L., Mancuso, S., & Muzzupappa, M. (2010). From 3D reconstruction to virtual reality: A complete methodology for digital archaeological exhibition. *Journal of Cultural Heritage*, *11*(1), 42–49. doi:10.1016/j.culher.2009.02.006

Bunny. (2018). *Brown wooden bunny*. Retrieved from: http://archives.algomau.ca/main/node/25490

Burdea, G. C., & Coiffet, P. (2003). *Virtual reality technology*. New York, NY: John Wiley & Sons. doi:10.1162/105474603322955950

Bustillo, A., Alaguero, M., Miguel, I., Saiz, J. M., & Iglesias, L. S. (2015). A flexible platform for the creation of 3D semi-immersive environments to teach Cultural Heritage. *Digital Applications in Archaeology and Cultural Heritage*, *2*(4), 248–259. doi:10.1016/j.daach.2015.11.002

Carrozzino, M., & Bergamasco, M. (2010). Beyond virtual museums: Experiencing immersive virtual reality in real museums. *Journal of Cultural Heritage*, *11*(4), 452–458. doi:10.1016/j.culher.2010.04.001

Casu, A., Spano, L. D., Sorrentino, F., & Scateni, R. (2015). RiftArt: Bringing Masterpieces in the Classroom through Immersive Virtual Reality. In *Eurographics Italian Chapter Conference* (pp. 77-84). Boston, MA: Academic Press.

Ch'ng, E., Cai, Y., & Thwaites, H. (2018). Special Issue on VR for Culture and Heritage: The Experience of Cultural Heritage with Virtual Reality: Guest Editors' Introduction. *Presence (Cambridge, Mass.)*, *26*(03), iii–vi. doi:10.1162/pres_e_00302

Corcoran, F., Demaine, J., Picard, M., Dicaire, L. G., & Taylor, J. (2002, April). Inuit3d: An interactive virtual 3d web exhibition. In *Proceedings of the Conference on Museums and the Web 2002*. Boston, MA: Academic Press.

Correa, A. G., Borba, E. Z., Lopes, R., Zuffo, M. K., Araujo, A., & Kopper, R. (2017, March). User experience evaluation with archaeometry interactive tools in virtual reality environment. In *Proceedings of 3D User Interfaces (3DUI)*, *2017 IEEE Symposium on* (pp. 217-218). IEEE.

Dalgarno, B., & Lee, M. J. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*, *41*(1), 10–32. doi:10.1111/j.1467-8535.2009.01038.x

Davis, F. D. M. (1989, September). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Management Information Systems Quarterly*, *13*(3), 319–340. doi:10.2307/249008

Digitized Bunny. (2018). *Brown wooden bunny*. Retrieved from: https://sketchfab.com/models/44ce7f1dfdd94aeaba8ffd5951275598

Digitized Dog. (2018). *Dog*. Retrieved from: https://sketchfab.com/models/39b78840da6147599878b1e63349f1bb

Dog. (2018). *Brown sitting dog*. Retrieved from: http://archives.algomau.ca/main/node/25489

Dumas, J. S., & Redish, J. (1999). A practical guide to usability testing. Portland, OR: Intellect Books.

Fabola, A., Miller, A., & Fawcett, R. (2015, September). Exploring the past with Google Cardboard. In *Digital Heritage, 2015* (Vol. 1, pp. 277–284). IEEE. doi:10.1109/DigitalHeritage.2015.7413882

Fang, T. Y., Wang, P. C., Liu, C. H., Su, M. C., & Yeh, S. C. (2014). Evaluation of a haptics-based virtual reality temporal bone simulator for anatomy and surgery training. *Computer Methods and Programs in Biomedicine*, *113*(2), 674–681. doi:10.1016/j.cmpb.2013.11.005 PMID:24280627

Fernandez-Palacios, B. J., Morabito, D., & Remondino, F. (2017). Access to complex reality-based 3D models using virtual reality solutions. *Journal of Cultural Heritage*, *23*, 40–48. doi:10.1016/j.culher.2016.09.003

Fokides, E. (2017). A model for explaining primary school students' learning outcomes when they use multi-user virtual environments. *Journal of Computers in Education*, *4*(3), 225–250. doi:10.100740692-017-0080-y

Freina, L., & Ott, M. (2015). A literature review on immersive virtual reality in education: state of the art and perspectives. *eLearning & Software for Education*, (1). Retrieved from https://www.ceeol.com/search/article-detail?id=289829

Frog. (2017). *Frog – small artifact series*. Retrieved from: http://archives.algomau.ca/main/node/25494

Gaitatzes, A., Christopoulos, D., & Roussou, M. (2001, November). Reviving the past: cultural heritage meets virtual reality. In *Proceedings of the 2001 conference on Virtual reality, archeology, and cultural heritage* (pp. 103-110). ACM. 10.1145/584993.585011

Garcia-Ruiz, M. A., Santana-Mancilla, P. C., & Gaytan-Lugo, L. S. (2016). measuring technology acceptance of makey makey as an input device in a human-computer interaction class. In *Proceedings of EdMedia 2016: World Conference on Educational Media and Technology*. Association for the Advancement of Computing in Education.

Garcia-Ruiz, M. A., Santana-Mancilla, P. C., & Gaytan-Lugo, L. S. (2017). A usability study on low-cost virtual reality technology for visualizing digitized Canadian cultural objects: Implications in education. In *Proceedings of EdMedia 2017: World Conference on Educational Media and Technology*. Association for the Advancement of Computing in Education.

Gimp. (2018). Retrieved from: https://www.gimp.org/

Gomes, L., Bellon, O. R. P., & Silva, L. (2014). 3D reconstruction methods for digital preservation of cultural heritage: A survey. *Pattern Recognition Letters*, *50*, 3–14. doi:10.1016/j.patrec.2014.03.023

Gonizzi Barsanti, S., Caruso, G., Micoli, L. L., Covarrubias Rodriguez, M., & Guidi, G. (2015). 3D visualization of cultural heritage artifacts with virtual reality devices. In *25th International CIPA Symposium 2015* (*Vol. 40*, No. 5W7, pp. 165-172). Copernicus Gesellschaft mbH.

Guarnieri, A., Remondino, F., & Vettore, A. (2006). Digital photogrammetry and TLS data fusion applied to Cultural Heritage 3D modeling. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *36*(5). Retrieved from http://3dom.fbk.eu/sites/3dom.fbk.eu/files/pdf/Guarnieri_etal_ISPRSV06.pdf

Jones, G., & Christal, M. (2002). *The future of virtual museums: On-line, immersive, 3D environments.* Created Realities Group. Retrieved from: http://w.created-realities.com/pdf/Virtual_Museums.pdf

Kapuire, G. K., Winschiers-Theophilus, H., Stanley, C., Maasz, D., Chamunorwa, M., Møller, R. H., & Gonzalez-Cabrero, D. (2017). Technologies to promote the inclusion of Indigenous knowledge holders in digital cultural heritage preservation. *International Conference on Culture & Computer Science*.

Kirkwood, A. (2015, June). Teaching and learning with technology in higher education: blended and distance education needs "joined-up thinking" rather than technological determinism. *Open Learning: The Journal of Open, Distance and e-Learning*, 1–16.

Kuusela, H., & Paul, P. (2000). A comparison of concurrent and retrospective verbal protocol analysis. *The American Journal of Psychology*, *113*(3), 387–404. doi:10.2307/1423365 PMID:10997234

Levoy, M., Pulli, K., Curless, B., Rusinkiewicz, S., Koller, D., Pereira, L., & Shade, J. (2000, July). The digital Michelangelo project: 3D scanning of large statues. In *Proceedings of the 27th annual conference on Computer graphics and interactive techniques* (pp. 131-144). ACM Press/Addison-Wesley Publishing Co. 10.1145/344779.344849

Linder, W. (2009). *Digital photogrammetry*. Berlin: Springer. doi:10.1007/978-3-540-92725-9

Lloyd, J. (2016, October). Contextualizing 3D Cultural Heritage. In *The Proceedings of Euro-Mediterranean Conference* (pp. 859-868). Springer International Publishing.

Matter and Form. (2018). Retrieved from: https://matterandform.net/scanner

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education*, *70*, 29–40. doi:10.1016/j.compedu.2013.07.033

Meshlab. (2018). Retrieved from: http://www.meshlab.net/

Munumer, E., & Lerma, J. L. (2015, September). Fusion of 3D data from different image-based and range-based sources for efficient heritage recording. In Digital Heritage, 2015 (Vol. 1, pp. 83-86). IEEE.

Nielsen, J. (2000). *Why you only need to test with 5 users*. Retrieved from: https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/

Nielsen, J. (2012). *Usability 101: Introduction to usability*. Retrieved from: https://www.nngroup.com/articles/usability-101-introduction-to-usability/

Ott, M., & Pozzi, F. (2011). Towards a new era for Cultural Heritage Education: Discussing the role of ICT. *Computers in Human Behavior*, *27*(4), 1365–1371. doi:10.1016/j.chb.2010.07.031

Pavlidis, G., Koutsoudis, A., Arnaoutoglou, F., Tsioukas, V., & Chamzas, C. (2007). Methods for 3D digitization of Cultural Heritage. *Journal of Cultural Heritage*, *8*(1), 93–98. doi:10.1016/j.culher.2006.10.007

Pedersen, I., Gale, N., Mirza-Babaei, P., & Reid, S. (2017). More than meets the eye: The benefits of augmented reality and holographic displays for digital cultural heritage. *Journal on Computing and Cultural Heritage*, *10*(2), 11. doi:10.1145/3051480

Pieraccini, M., Guidi, G., & Atzeni, C. (2001). 3D digitizing of cultural heritage. *Journal of Cultural Heritage*, *2*(1), 63–70. doi:10.1016/S1296-2074(01)01108-6

Portales, C., Alonso-Monasterio, P., & Vinals, M. J. (2017). 3D virtual reconstruction and visualisation of the archaeological site Castellet de Bernabe (Lliria, Spain). Virtual Archaeology Review, 8(16), 75. doi:10.4995/var.2017.5890

Posey, G., Burgess, T., Eason, M., & Jones, Y. (2010, March). The Advantages and Disadvantages of the Virtual Classroom and the Role of the Teacher. In *Proceedings of Southwest Decision Sciences Institute Conference* (pp. 2-6). Decision Sciences Institute.

Potenziani, M., Callieri, M., Dellepiane, M., Corsini, M., Ponchio, F., & Scopigno, R. (2015). 3DHOP: 3D heritage online presenter. *Computers & Graphics*, *52*, 129–141. doi:10.1016/j.cag.2015.07.001

Rae, J., & Edwards, L. (2016, January). Virtual reality at the British Museum: What is the value of virtual reality environments for learning by children and young people, schools, and families? *Proceedings of MW2016: The Annual Conference Museums and the Web*.

Remondino, F., & El-Hakim, S. (2006). Image-based 3D modelling: A review. *The Photogrammetric Record*, *21*(115), 269–291. doi:10.1111/j.1477-9730.2006.00383.x

Rubin, J., & Chisnell, D. (2008). *Handbook of usability testing: how to plan, design, and conduct effective tests*. Indianapolis, IN: John Wiley & Sons.

Santos, P., Pena Serna, S., Stork, A., & Fellner, D. (2014). The potential of 3D internet in the cultural heritage domain. In M. Ioannides & E. Quak (Eds.), *A Roadmap in Digital Heritage Preservation on 3D Research Challenges in Cultural Heritage (Vol. 8355)*. New York, NY: Springer-Verlag. doi:10.1007/978-3-662-44630-0_1

Sauro, J. (2011). *A Practical guide to the system usability scale: Background, benchmarks & best practices*. Denver, CO: CreateSpace.

Sherman, W. R., & Craig, A. B. (2002). *Understanding virtual reality: Interface, application, and design*. San Francisco, CA: Morgan Kauffmann/Elsevier.

Sketchfab. (2018). Retrieved from: https://sketchfab.com/

Sketchfab Controls. (2017). *Navigation and Controls*. Retrieved from: https://help.sketchfab.com/hc/en-us/articles/202509026-Navigation-and-Controls

Sooai, A. G., Sumpeno, S., & Purnomo, M. H. (2016, April). User perception on 3D stereoscopic cultural heritage ancient collection. In *Proceedings of the 2nd International Conference in HCI and UX Indonesia 2016* (pp. 112-119). ACM. 10.1145/2898459.2898476

Tsirliganis, N., Pavlidis, G., Koutsoudis, A., Papadopoulou, D., Tsompanopoulos, A., Stavroglou, K., & Chamzas, C. (2004). Archiving cultural objects in the 21st century. *Journal of Cultural Heritage*, *5*(4), 379–384. doi:10.1016/j.culher.2004.04.001

Usability Test. (2017). *Running a usability test*. U.S. Department of Health & Human Services. Retrieved from: https://www.usability.gov/how-to-and-tools/methods/running-usability-tests.html

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204. doi:10.1287/mnsc.46.2.186.11926

Virvou, M., & Katsionis, G. (2008). On the usability and likeability of virtual reality games for education: The case of VR-ENGAGE. *Computers & Education*, *50*(1), 154–178. doi:10.1016/j.compedu.2006.04.004

Zaharias, P.A. (2004). Usability and e-learning: the road towards integration. *eLearn Magazine, 2004*(6), 4.

Zaharias, P. A. (2006). Usability evaluation method for e-learning: Focus on motivation and learning. In *Proceedings of CHI 2006* (pp. 1571-1576), Montreal, Canada: ACM. 10.1145/1125451.1125738

ADDITIONAL READING

Donghui, C., Guanfa, L., Wensheng, Z., Qiyuan, L., Shuping, B., & Xiaokang, L. (2017). Virtual reality technology applied in digitalization of cultural heritage. *Cluster Computing*. doi:10.100710586-017-1071-5

Doulamis, N., Doulamis, A., Ioannidis, C., Klein, M., & Ioannides, M. (2017). Modelling of Static and Moving Objects: Digitizing Tangible and Intangible Cultural Heritage. In *Mixed Reality and Gamification for Cultural Heritage* (pp. 567–589). Cham: Springer International Publishing; doi:10.1007/978-3-319-49607-8_23

Guidi, G., Micoli, L. L., Gonizzi, S., Brennan, M., & Frischer, B. (2015). Image-based 3D capture of cultural heritage artifacts an experimental study about 3D data quality. In 2015 Digital Heritage (pp. 321–324). IEEE. doi:10.1109/DigitalHeritage.2015.7419514

Jiménez Fernández-Palacios, B., Morabito, D., & Remondino, F. (2017). Access to complex reality-based 3D models using virtual reality solutions. *Journal of Cultural Heritage*, *23*, 40–48. doi:10.1016/j.culher.2016.09.003

Kalay, Y. (2008). Preserving Cultural Heritage through Digital Media. In Y. Kalay, T. Kvan, & J. Afflek (Eds.), *New Heritage: New Media and Cultural Heritage* (pp. 1–10). New York: Routledge.

Kolay, S. (2016). Cultural Heritage Preservation of traditional Indian Art through virtual new-media. *Procedia: Social and Behavioral Sciences*, *225*, 309–320. doi:10.1016/j.sbspro.2016.06.030

Nagata, J. J., Garcia-Bermejo Giner, J. R., & Martinez Abad, F. (2016). virtual heritage of the territory: Design and implementation of educational resources in augmented reality and mobile pedestrian navigation. *IEEE Revista Iberoamericana de Tecnologias Del Aprendizaje*, *11*(1), 41–46. doi:10.1109/RITA.2016.2518460

Tan, B., Cai, Y., Zhang, Y., Wu, X., Chen, Y., & Yang, B. (2016). Virtual reality continuum for heritage at Haw Par Villa in Singapore. In *Proceedings of the Symposium on VR Culture and Heritage - VRCAI '16* (pp. 71–74). New York, NY: ACM Press. 10.1145/3014027.3014030

White, M., Mourkoussis, N., Darcy, J., Petridis, P., Liarokapis, F., Lister, P., ... Gaspard, F. (2004). ARCO - an architecture for digitization, management and presentation of virtual exhibitions. In *Proceedings Computer Graphics International, 2004* (pp. 622–625). IEEE; doi:10.1109/CGI.2004.1309277

KEY TERMS AND DEFINITIONS

3D Model: A 3D computer graphics object composed of polygons such as triangles or rectangles.

3D Scanner: Digital device connected to a computer used to digitize an object in 3D, capturing reference points in X, Y, and Z axes, and sometimes acquiring color from those reference points.

Anishinaabe: Autonym for a group of culturally-related indigenous peoples in Canada and northern United States including the Algonquin, Chippewa, Odawa, Ojibwe, Oji-Cree, Mississaugas, and Potawatomi peoples.

Cultural Object: An object made by people for a spiritual and/or practical purpose or activity that may have functional and/or artistic relevance.

Immersion: Psycho-physiological user perception of being physically present in a virtual environment.

Interpupillary Distance: The term refers to distance between the user's pupils, employed in virtual reality headsets and other VR-related visualization equipment.

Intrinsic Motivation: User or learner's behavior that is based on internal rewards and the motivation to engage in them. It arises from within the person because it is naturally satisfying to him/her.

Kanban Board: A workflow and work visualization chart describing activities flow within a project, originally created in the 1940s by Toyota.

Model Mesh: Collection of reference points in X, Y, and Z axes that define a graphical 3D shape with width, height, and depth.

Texture: An image that is associated to a 3D model and is generated by 3D scanners that capture color, which forms the surface ("skin") of the model.

APPENDIX

Table 5. Technology acceptance model (TAM2) questionnaire

	Strongly Disagree	Moderately Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Moderately Agree	Strongly Agree
Intention to Use							
Assuming I have access to the system, I intend to use it.							
Given that I have access to the system, I predict that I would use it.							
Perceived Usefulness							
Using the system improves my performance in my activity as student.							
Using the system in my activity as student increases my productivity.							
Using the system enhances my effectiveness in my activity as student.							
I find the system to be useful in my activity as student.							
Perceived Ease of Use							
My interaction with the system is clear and understandable.							
Interacting with the system does not require a lot of my mental effort.							
I find the system to be easy to use.							
I find it easy to get the system to do what I want it to do.							
Subjective Norm							
People who influence my behavior think that I should use the system.							
People who are important to me think that I should use the system.							
Voluntariness							
My use of the system is voluntary.							
My supervisor does not require me to use the system.							
Although it might be helpful, using the system is certainly not compulsory in my activity as student.							
Image							
People in my school who use the system have more prestige than those who do not.							
People in my school who use the system have a high profile.							
Having the system is a status symbol in my school activity as student							
Relevance							
In my activity as student, usage of the system is important.							
In my activity as student, usage of the system is relevant.							
Output Quality							
The quality of the output I get from the system is high.							
I have no problem with the quality of the system's output.							
Result Demonstrability							
I have no difficulty telling others about the results of using the system.							
I believe I could communicate to others the consequences of using the system.							
The results of using the system are apparent to me.							
I would have difficulty explaining why using the system may or may not be beneficial.							

Source: Adapted from Venkatesh & Davis (2000)