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Reviving Classical Drama: virtual reality and experiential learning in a traditional classroom

Eleni Bozia <bozia_at_ufl_dot_edu>, University of Florida

Abstract

Over the past decades the advancement of technology and its subsequent introduction to the humanities has led to the development of several applications that enhance study and research in areas such as Classics, archaeology, epigraphy, and linguistics. The focus of digital humanists and other humanities scholars has turned to the efficient storage of information that facilitates search, comparative studies, accessibility, and consequently research. The common point of reference for the aforementioned applications is that they do not involve the need for the scholar to “physically” be in a virtual space. In areas, such as archaeology and epigraphy, the creation of projects that provide access to 3D models of the artifacts as well as to virtual replications of ancient sites has resulted in the opening of new areas of research and reconsideration of traditional research issues. Also, [Forte et al. 1997] argue that digital visualizations may make the ancient world more accessible to a larger audience. One may comprehend the structure of a vase and analyze its artistic patterns by zooming and relighting it. A problem that is yet to be considered, though, is how a scholar and a student are to perceive Classical drama, the theatrical space, the distances between the actors, the chorus, and the audience, the logistics of the performance, and the cultural aspects at play. This paper discusses the importance of experiential learning and the use of virtual reality as a means of promoting traditional edification methods, virtually recreating the actuality of the stage, and presents the Magic Mirror Theater, a web application designed to facilitate the study of Classical drama.

Introduction

Over the past decades the advancement of technology and its subsequent introduction to the humanities has led to the development of several applications that enhance study and research in disciplines such as Classics, History, English, and Linguistics. The focus of digital humanists and other humanities scholars has turned to the efficient storage of information that facilitates search, comparative studies, accessibility, and consequently research. The common point of reference for the aforementioned fields is that they do not involve the need for the scholar to “physically” be in a virtual place. On the other hand, in areas, such as archaeology and epigraphy, the creation of projects that provide access to 3D models of the artifacts as well as to virtual replications of ancient sites has resulted in the opening of new areas of research and reconsideration of traditional research methods as well as questions.[1] [Forte et al. 1997] argue that such digital visualizations may make the ancient world more accessible to a larger audience. A problem that is yet to be considered, though, is how a scholar and a student are to perceive Classical drama, the theatrical place, the distances between the actors, the chorus, and the audience, the logistics of the performance, and the cultural aspects at play. This paper discusses the importance of experiential learning and the use of mixed reality as a means of promoting traditional edification methods, virtually recreating the actuality of the stage, and presents the Magic Mirror Theater, a web application designed to facilitate the understanding of Classical drama. 1

There have been several attempts at reviving the circumstances of performance in the actual physical place. Studies have focused on information that is provided to us through the texts, inscriptional evidence as well as archaeological and spatial constituents. Walton in his 1989 collection of essays titled *Living Greek Theater: A Handbook of Classical* 2

Performance and Modern Production furnishes the reader with information on classical performance and then re-conceptualizes it on the contemporary stage, while discussing staging issues. Mary-Kay Gamel through the Ajax project in 2011, one of the most recent attempts at restaging Classical drama, reconstructed *Ajax*, modernized the setting, and reshaped the characters to imbue them with modernity while retaining the classical aura. David Gowen [Gowen 1999] presents a brief overview of the Archive of Performances of Greek and Roman Drama at the University of Oxford. Helene Foley [Foley 1999] [Foley 2012] has developed profoundly insightful studies into the reconstruction of performances. Richard Beacham [Beacham 1999] reviews various projects in the reconstruction and study of ancient theaters through virtual reconstructions.[2] Several of these studies are enveloped within a concept of contemporization of drama and contextualization within modern society. [Hartigan 1995] discusses Greek drama on the American stage. [Michelakis 2010] expands the parameters and studies the socio-political forces that drive modern reconstructions, and [Slater 2015] discusses a performance of *Trojan Women* on the American stage against a contemporary backdrop. The above brief survey indicates that unlike other literary genres, Classical drama requires a two-pronged approach — a theoretical one that encompasses literary and socio-political attributes of the plays and a dramaturgical one that is meant to comprehend the practical aspects of works that were meant to be performed and not simply read. Therefore, when one teaches Classical drama, the literary analyses overshadow a pivotal aspect of those works. Bibliographical surveys of modern performances, even though they start from the dramaturgical premise, provide the readers with a different yet still literary discussion of a performance, with the reader missing the dramatic component. Furthermore, digital reconstructions of ancient venues and/or performances forego a vital constituent that is the individual and his/her sense of space. Therefore, it seems that the only all-inclusive solution that will lend itself to traditional courses is the creation of a mixed-reality environment, which will allow the user to “be” in the theatrical space, experience the performance, and attempt different staging possibilities in a more realistic manner, incorporating enhanced synaesthetic approaches and constituting for the participant the foundation of constructivist learning that can only be achieved through experiential learning practices.

Experiential Learning

The advantages of experiential learning were apprehended very early on. Dewey, an American philosopher, psychologist, and educational reformer in the late 19th–early 20th century, first suggested and implemented the paradigm of effective teaching that combines traditional methodologies with real-life experiences so as to achieve the most effective and truly pedagogical experiences. He first tested this reconsideration of traditional teaching in his experimental Laboratory School in Chicago and in 1896 published his book *The School and Society* in which he explicates his rationale, methods, methodology, and the practical results.[3] According to Dewey, experiential learning is developed by and based on the following three “unities”: 3

1. the unity of abstract knowledge and doing in the real world
2. the unity of action and reflection and
3. the unity of the individual with the community

The aforementioned three aspects of experiential learning are on par with the precepts of digital humanities theories and pedagogy.[4] More specifically, there is a concatenated reality of the interwoven existence of knowledge, the individual, the environment (which could either be further knowledge or other people), and finally the overarching reality of perception of all the above that has prompted the birth of digital humanities. Therefore, since this initial appreciation of experiential learning by Dewey, there have been extensive studies on the pivotal role of digital pedagogy that may include teaching of new technologies or digital critical thinking to reconsider traditional research questions [Barmpoutis et al. 2014]. [Hirsch 2012] assembled a voluminous work on digital humanities pedagogy that aims at (re)defining pedagogy. The contributors argue that new technologies, digital interactions with traditional research topics, and the collaborative spirit of such trajectories enhance critical thinking that only stems from new technologies but is not dependent upon them. [McCarty 2012, 46] presents the Ph.D. in Digital Humanities as “not just a framework for research…but is itself empirical research into the best framework with which to further develop the intellectual culture of digital humanities.” [Mahony et al. 2012, 225] contend that: “Skills training is not research training,” as “the knowledge gained is transient.” “Thinking skills are the most important because they are the most deeply embedded and the most 4 transferable.” [Ives 2014] explores the same ideas of applying new technologies, but also of reinforcing traditional methods through the lens of digital methodologies. In the areas of classical studies, the significance of teaching via digital methods and against the backdrop of digital methodologies is extensively discussed in [Bodard et al. 2016]. Finally, in a broader sense but against that same backdrop of new media and its relation with the user, [Manovich 2001] discusses visual and media cultures and the ways in which reality and illusion are (re)created as well as their contact with and influence of the viewer and vice versa.

Experiencing Classical Drama

Based on the aforementioned attempts at theatrical recreation as well as the undeniable advantages of experiential learning, what is the principal component lacking in traditional teaching and research of Classical drama? What are the inherent characteristics of theatrical performances that cannot be captured via traditional readings, recitations, or class performances? 5

Scholars and students of classical studies very early familiarize themselves with the technical knowledge regarding, for instance, the number of actors (2-3 male actors), the members of the chorus (12-15 in tragic plays, 24 in comic plays), the fact that orchestras traditionally were circular (with the exception of the theater of Thorikos, where it is rectangular), and the diameter of the orchestra in the theater of Epidaurus (20m). However, how feasible is it for them to apply this knowledge to the real world, and, more specifically, is it possible to truly comprehend the movements of the limited number of actors when they need to leave the stage, change costumes in order to impersonate another character, and then return while the chorus is singing for 150 lines? Also, can modern audiences really understand the performance of female roles by male actors? Finally, is the overall perception of ancient productions possible when one is not given the opportunity to actually walk in the theater, feel the connection, both physical and dramatic, between actors and audience, and also “experience” the performance in its actual natural surroundings?[5] 6

Theater is the space *par excellence* that necessitates and effectuates the confluence of several parameters — stage as a construction, people both as actors and viewers, and the cultural ambience of the play itself as well as of the time when the performance takes place. Absence of any of the above not only sullies the equilibrium, but also denotes utter failure of the endeavor. The place, the individual as an actor or viewer within that place, and the cultural context within which plays were written and performed in the ancient world need to be recaptured so as to acquire a historical, cultural, and theatrical situatedness, thus procuring a notional space for the theatrical performance. 3D models of theatrical venues can easily be constructed, and individuals who reenact plays can also act within any place. So arguably the missing component is the intangible, namely the co-existence of space and actors as well as the cultural aura. Virtual reality and the creation of immersive virtual worlds can effectuate tangibility of what thus far has been considered intangible cultural heritage.[6] Therefore, as theater presents a unique concatenation of tangible cultural heritage — theatrical construction — and intangible cultural heritage — the plays, the actors, and the props — the only feasible way to re-experience all the above as participants ourselves is the creation of a mixed-reality virtual environment.[7] 7

Thus far the research community has attempted to fill the vacuum with the production of historical games, the emergence of which alone is enough to prove the exigency for the recreation of past worlds if we are to achieve a more profound level of understanding. The creation of experiences [Hobbs et al. 2006] and the sense of place [Goel et al. 2011] are the two pivotal pillars of understanding lacking in traditional historical studies. [Chapman et al. 2016] discuss extensively the nascent area of historical game studies within the context of serious gaming applications.[8] They argue in favor of the theory, content, and purposes that such games serve that distinguish them from generalized game studies. [Mortara et al. 2014] and [Champion 2015] also extensively analyze this developing field, envisioning reconsideration in the approaches of history. A basic point of historical gamification, however, is that, albeit carrier of historical and cultural relatability for the players, it is not meant to insist on historical accuracy.[9] [Neville et al. 2010] also discuss the improved perception of situatedness in 3D digital game-based learning, but admit to its limitations regarding accuracy.[10] 8

Virtual and Mixed Reality

Gamification of history seems to be an obvious response to the need to envision yourself as a participant in a historical event, therefore better comprehending the cultural and socio-political issues at play. Virtual worlds constitute exactly this (digital) space — the place, the ambience, and the people.[11] [Bainbridge 2007] describes a virtual world as "an electronic environment that visually mimics complex physical spaces, where people can interact with each other and with virtual objects, and where people are represented by animated characters." *Second Life* is a representative example of the freedom of the individual to experience something else, beyond each one's contemporaneity. 9

This section furnishes a survey of virtual reality applications that attempt to minimize the lack of physical contact between their field of study and the individual user and then proceeds to discuss the enhanced reality(ies) available through mixed-reality environments. Recent advances in computer graphics technology have made the use of virtual reality and/or experiential-learning methods in projects on classical studies possible. These projects can be divided into three main categories: a) projects that involve the development of 3D virtual models of ancient objects, b) simulations of 3D virtual environments, and c) experiential-learning systems. All three categories of projects have added significantly to the promotion of classical research.[12] 10

3D models of ancient sites and objects

The "Rome reborn" project (http://www.romereborn.virginia.edu) is an international initiative whose goal is the creation of 3D digital models that illustrate the urban development of Ancient Rome from the first settlement to the early Middle Ages. The project started in 1997 and is an ongoing collaboration between the Virtual World Heritage Laboratory at the University of Virginia, the UCLA Experiential Technology Center, and many other European institutes. The online published version of the project consists of medium quality rendered still images and videos of the 3D models. 11

The "Digital Roman Forum" project (http://dlib.etc.ucla.edu/projects/Forum) of the former UCLA Cultural Virtual Reality Laboratory produced the 3D digital model of the Roman Forum as it appeared in late antiquity. The project started in 1997 and was completed in 2003. The produced 3D models were included in the "Rome reborn" project. The online published version of the project consists of rendered still images (in small, medium, and high quality) and panorama videos of the 3D models. The reconstruction was based on literary evidence. 12

The UCLA Experiential Technology Center (http://etc.ucla.edu) continues the work of the former UCLA Cultural Virtual Reality Laboratory and has designed several 3D digital models of archaeological sites in Bolivia (Island of the sun), Egypt (Lighthouse of Alexandria, Karnak), Israel (Qumran), Italy (Colosseum, Basilica Maxentius, Villa of the papyri, and others), Spain (Cathedral of Santiago de Compostela), and Turkey (Digital Anatolia). The projects focus on the study of the architectural and urban design of the aforementioned sites. 13

The "Digital Egypt for Universities" project (http://www.casa.ucl.ac.uk/digital_egypt/3d/) is an on-line library of 3D models from several archaeological sites in Egypt developed at the University College London. The 3D models were created between 2000-2003 and are available on-line in 3D file format VRML. Rendered images and videos of the 3D models are also available on-line. 14

The "Ashes2Art" initiative (http://www.coastal.edu/ashes2art/) at the Coastal Carolina University focuses on the development of educational interactive digital media presentations of Alexandria, Delphi, and Renaissance Florence. The interactive presentations include photographic material, text, and 3D models. The projects were the results of a collaboration between Alexandria University and Arkansas University and are available on-line in the form of interactive Java applets. This project was in part funded by the NEH. 15

Simulations of 3D virtual environments

Researchers from the NYU Media Research Lab and the UCLA Computer Science department have developed a research application that populates 3D reconstructed models of archaeological sites with autonomous virtual avatars. The goal of this project is to quantitatively analyze and understand the human activities and the use of the spaces in the Great Temple of Petra, Jordan. The results of this project are available here: http://www.cs.ucla.edu/~dt/papers/iva06/iva06.pdf 16

Computer simulation of ancient sailing was the focus of an interdisciplinary project at the University of Calgary in 1999. The goal of this project was to understand the strengths and limitations of ancient transportation means. http://www.cnrs-scrn.org/northern_mariner/vol09/nm_9_2_11-22.pdf 17

“Virtual Vaudeville” is a virtual 3D reconstruction of a Victorian theater, a live performance simulation system that provides a sequence of 3D computer animations. http://www.virtualvaudeville.com/ 18

Interactive environments for experiential learning

An interactive gaming environment is used in the project titled “History simulation for teaching early modern British history” at the University of South Carolina. The project's main goal is to develop a game-based classroom technology that can be used in general as a prototype for educational games. The educational content is gradually presented to the users by solving game challenges. 19

“Second Life” is an interactive virtual environment that has been used by many academic institutes as a platform for embodied experiential learning. Professors and students of law have designed a digital model of a virtual court building to practice law, using Second Life as a classroom software application. There are similar experiential learning uses of Second Life reported in other academic fields. The Second Life Educational Directory lists all academic institutes that use this tool (http://wiki.secondlife.com/wiki/Second_Life_Education_Directory). 20

Additionally, there have been consistent attempts to visualize the text differently — reconsidering its linearity (https://twinery.org/), visualizing theatrical texts [Roberts-Smith 2013], or simply producing an experience beyond reading the text ([Gabriele 2010]; [Galey 2009]; [Roberts-Smith 2010]; [Roberts-Smith 2013]). 21

The development of the aforementioned projects clearly indicates that academic communities consider it necessary to enhance traditional research and teaching methodologies and that virtual reality can play a significant role in this endeavor. However, it is obvious that the existing projects are limited either by the modality of the content or by the delivery mechanism of the educational material. Additionally, they all lack the synaesthetic parameter that can actually grant a degree of reality and understanding that can be afforded through the stimulation of more senses than vision.[13] More specifically, the majority does not provide the 3D models to the users, thus limiting their interaction to predefined viewing angles (still images), or pre-recorded videos. Flynn actually criticizes the lifelessness of 3D-digitized virtual replicas of places and artifacts and proceeds with an extensive discussion on the lack of embodiment that results in lack of understanding [Flynn 2007, 354–364]. Therefore, an advanced solution to this limitation that would also enhance the perception of the theatrical space is the creation of a mixed reality [Milgram at al. 1994], a virtual world that would also allow for the embodied participation of the users. 22

Experiential learning is a well-studied research area, and the connection between embodied action and learning outcome has been extensively examined ([Alibali at al. 2007]; [Eisenberg et al. 2014, 344–8]; [Goldin-Meadow 1999]; [Lakoff 2001]; [Núñez 1999]).[14] Several researchers have emphasized the contribution of embodiment to learning and the apprehension of concepts ([Abrahamson et al. 2012]; [Alibali 2012]; [Eisenberg et al. 2014, 347–8]; [Goldin-Meadow 2009]). Additionally, there is strong scholarship in different academic fields to support that mixed-reality environments enhance the educational experiences, leading to better learning outcomes. [Lindgren et al. 2013] discuss extensively the advantages of mixed reality and present guidelines as to how this is to be achieved within a learning environment. 23

The Magic Mirror Theater project implements state-of-the-art technologies for experiential learning, using virtual reality and natural user interaction. The answer to practical issues and questions that tantalize the scholar and the student of Classical drama can be approached and perhaps answered via the design of this mixed-reality environment in which the users can view themselves as tridimensional avatars, play, act and react, practice their knowledge in a given topic, learn through their mistakes, and achieve a fundamental comprehension of their object of study.[15] The project essentially transforms the computer screen into a “mirror” where the users can see themselves acting inside the 3D models of ancient theaters and interacting with virtual objects, using intuitive natural gestures. Within these parameters, the Magic Mirror Theater utilizes the human cognitive ability that is enhanced when the body interacts with the environment.[16] 24

This is particularly vital when the object of study actually involves not only abstract notions that can be better conceptualized within a mixed-reality environment but also an actual physical place, as is the case with theatrical performances of ancient dramas. Second the project creates what Colella calls “participatory simulations,” also a paragon in understanding via constructivist learning [Colella 2000].

The concept behind this pilot prototype technique is to open the discussions on Classical drama and move them beyond the text. The Magic Mirror Theater is not meant to replace actual performances in the physical space. However, when limited by a semester-long curriculum, one finds herself resorting to mundane PowerPoint presentations and suggestive readings as well as theoretical performance possibilities. The presented pilot technique aims at offering the possibilities to students to virtually situate themselves into an ancient venue, observe the natural surroundings, and “experience” the feeling of moving and interacting in a setting that takes them beyond the regular classroom. 25

Embodied Experiential Learning and the Magic Mirror Theater

> Starting form this gaze that is, as it were, directed toward me, from the ground of this virtual space that is of the other side of the glass, I come back toward myself; I begin again to direct my eyes toward myself and to reconstruct myself and to reconstitute myself there where I am. [Foucault 1986, 24]

26

[Lindgren et al. 2013, 446] argue: “If physical movement *primes* mental constructs, such as language, then it may be that increasing an individual’s repertoire of conceptually grounded physical movement will provide fertile areas from which new knowledge structures can be developed.” Researchers exploring these potentials have undertaken various environments of mixed realities. [Chang et al. 2010] discuss the use of robotics. [Lindgren et al. 2011] experimented with body-based metaphors in which the students assumed the role of an asteroid to better conceive movement into space. Other types of virtual interaction have involved the creation of panoramas, as “it (the panorama) reveals itself as a navigable space, persistent throughout media history, which is charged with sociocultural implications.” [Kenderdine 2007, 302] and [Grau 2003, 7] argue that: “In virtual reality, the panoramic view is joined by sensorimotor exploration of an image space that gives the impression of a ‘living’ environment.” [Savin-Baden at al. 2010] discuss extensively the advantages of immersive virtual worlds and their effect in pedagogy against the backdrop of constructivist learning and the opportunities for participatory and social learning through fostered interactions between users.

The Magic Mirror Theater is a technologically advanced educational tool for the effective and comprehensive study of Classical drama. The program involves the 3D digitization of ancient theaters as well as other objects for theatrical performance (such as replicas of props, costumes, and mechanical devices).[17] An embodied environment for experiential learning and an intuitive natural user interface were developed that allow the users to interact with the system and the virtual objects using natural body motion and gestures. The users can walk in life-size replicas of Classical theaters, interact with virtual objects, using virtual-reality technology, and ultimately understand the circumstances of performance in the Greco-Roman world. 27

Thus far, teaching methodologies for Classical drama in higher education have been limited to the study of the plot from the original text in conjunction with secondary bibliography that provides information regarding the circumstances of performance based on archaeological and literary evidence. This method of studying and analysis of the text, however, has left gaps in knowledge and room for subjective, or even incorrect interpretations, especially when spatiotemporal interactions of the portrayed characters play a significant role in the study of the original text. Questions such as “How many dancers in circular arrangement can fit on the stage of the theater of Dionysus in Athens?” “What are the possible arrangements of the chorus on ancient theaters with rectangular stage?” “How much time does it take to walk from the center of the stage to the back stage in the theater of Epidaurus?” “What would be the appropriate size of props, costume accessories, and other machinery so as to be visible to everyone in the audience, including people in the back 28 rows?" cannot be easily answered by the traditional teaching methodologies in the humanities. To find the answers to such questions, one needs to combine archaeological, historical, topographical knowledge, and possibly to visit the archaeological sites in order to understand the size of the available spaces as well as the physical environment and its implicit role in the play.[18]

In this prototype technique the synergy of mixed reality, embodiment, and the users' own avatars is achieved so that the level of understanding is effectively increased. More specifically, the conception of place can be grasped as the user gets to be the avatar walking in the tridimensional space, and the usage of props enhances the apprehension of historical situatedness, as the users can navigate a space imbued with images and the culture of the past. Admittedly this is a component that is still lacking in games. [Friedman 1995] states that: "There could never be an 'objective' simulation free from 'bias'. Computer programs, like all texts, will always be ideological constructions." Similarly [Fleckenstein 2005, 164] maintains that: "Place is neither an imprint of our discursive regimes nor an impervious container that shapes our identities without being shaped in return. Rather, place is the product and the producer of a dynamic fusion of sign system, physical reality and interpretant." So the Magic Mirror Theater system intends to utilize the above parameters rather than consider them reductive by immersing the user as an avatar into the exact replicas of ancient theaters, thus procuring a conceptually productive co-existence of user, actual physical environment, and theatrical venue. 29

The classroom projector or computer screen can be used as a magic mirror in which the users can see themselves standing in the middle of a virtual theater, which is a real-life digital replica of the well-known ancient theater of Epidaurus. This mixed-reality system utilizes a low-cost depth/video camera, which is connected with the computer as a regular USB web-camera. Such depth cameras are available from many companies that produce devices for natural user interaction, such as gaming engines (Microsoft Kinect), peripheral devices (LeapMotion), laptops (Intel RealSense camera), and many others starting from $69 (retail price).[19] One of the key advantages of these devices is that they do not require any technological skill by the users. On the contrary, the users can use their natural body motion and everyday life gestures to give instructions to the computer. Scholars and students are found to be familiar with natural user interface platforms that already exist in the majority of households due to their affordable price range, according to national reports [Pew Report 2008]. This prototype system uses the information acquired from the depth sensor to instantly reconstruct the 3D body image of the user, which is displayed as a real-time 3D holographic video stream in the middle of the virtual theater. The camera follows the motion of the users, who can move, walk, act, dance as the corresponding motion is instantly transferred to their 3D holographic image in the virtual scene. The prototype system was built as an HTML5 application using webGL for the rendering of the 3D content (avatars and theater) and webSockets for communicating in real-time with the depth sensor. The depth sensor tracked in real time the body motion of the users by fitting a 25-joint skeletal model to their 3D silhouette using the J4K (Java for Kinect) library that was originally developed for real-time 3D body reconstruction and human avatar synthesis [Barmpoutis 2013]. The real-time sequence of tracked skeletons was transferred to the prototype system that displayed composed 3D scene. 30

The users can intuitively understand the size of the stage and the structure of the theater by simply walking in the virtual space and by visually comparing the size of their holographic body with the size of the depicted virtual elements of the theater, which is an automatic process of our brain that is triggered any time one visits a new space [Glenberg et al. 2008]. The users can also choose between 1st and 3rd person's view, hold virtual props, and replicate their body multiple times in the virtual space in various arrangements. The latter is a useful feature, as it facilitates the understanding of those parts that involve the members of the chorus (dancers), whose number varies across authors and plays. The Magic Mirror Theater educational system covers cross-disciplinary material on Classical drama, and its implementation is based on archaeological evidence on the number of actors and choristers, their gender restrictions (actors in Classical Greece were exclusively male), the theater in which it was originally performed, the season and time of the performance (relative to the sunrise or the sunset), the structure of the theater (type, size, auxiliary rooms available, etc.), as well as information about costumes and mechanical devices used during the performances. The material is presented to the users through an experiential-learning environment that can be used either by the instructor as a novel teaching tool, or by the scholar of Classical drama who will ultimately understand better the circumstances of performance in the Greco-Roman world by personally interacting with the aforementioned virtual objects. The ultimate 31 goal is to recreate not only the place itself but the ambience of that place as well.

Champion and Dave have discussed the possibilities of new technologies that achieve “visual fidelity,” [Champion et al. 32
2007, 335] but not enough to recreate the place with its atmosphere and emphasize on the need for “a more advanced representation of such places (that) may include their contextual settings (e.g. landscapes) and the ability to navigate through them” [Champion et al. 2007, 340]. [Neville et al. 2010, 623] in their discussion on 3D digital game-based learning admit that: “Determining which types of perspective are amenable to the instructional goals and virtual representations of literary and historical 3D-DGBL is perhaps the most difficult task facing designers. Creating a more subjective experience by collapsing the distance between the real and the virtual, the Self and the Other, through a first-person point of view emphasizes the transparent immediacy of the game space.” The Magic Mirror Theater enables you to find yourself in the virtual environment and be in a position to decide which is the role that the Self wishes to assume, while also embedding the Self in the space of the Other.

The Magic Mirror Theater prototype environment

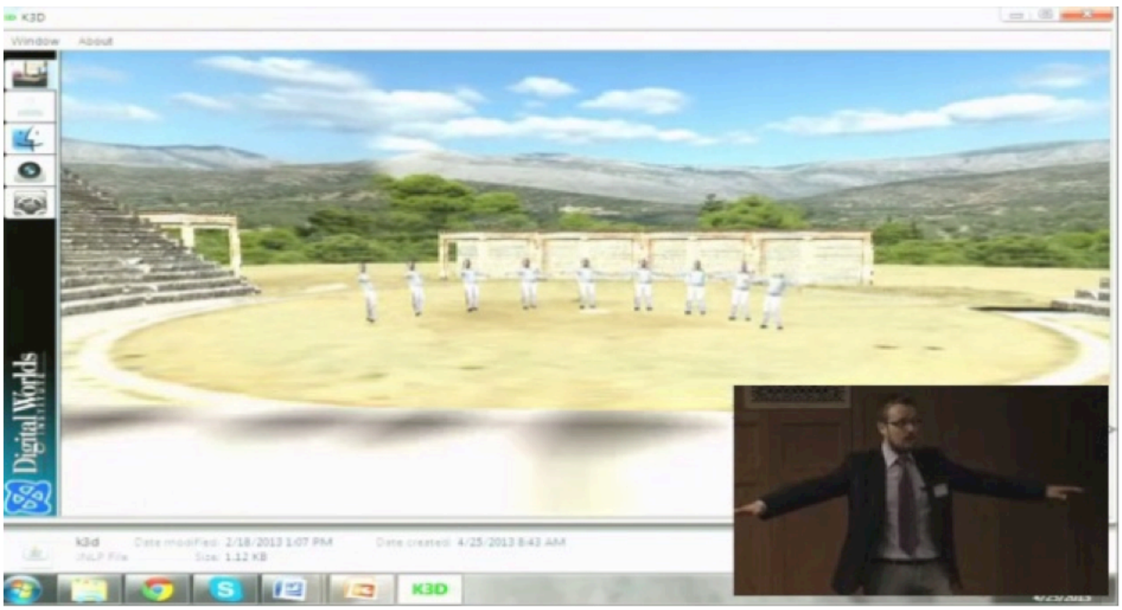

Figure 1.

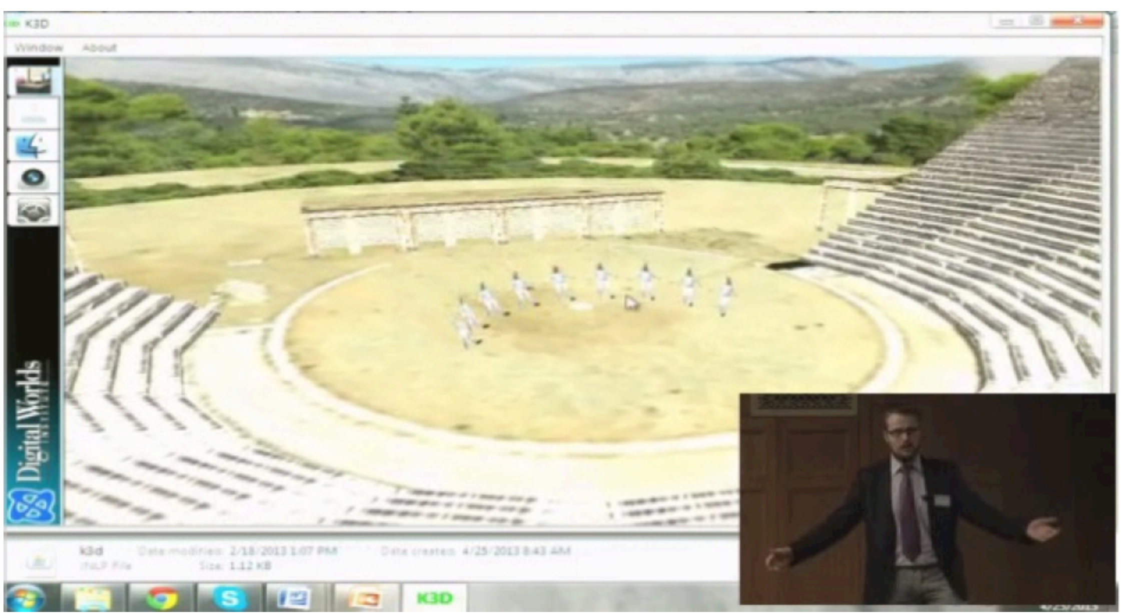

Figure 2.

Screenshots of the prototype Magic Mirror Theater mixed-reality system for experiential learning. The classroom 33
projector or computer screen is transformed into a magic mirror in which the users can see themselves standing in a virtual environment (the corresponding images from the real environment are shown in the lower right corner of each image). The images show the user walking in the environment, interacting with virtual objects, and wearing virtual costumes. Note that these virtual objects and clothing do not exist in the real environment (shown at the lower right corner of figures 1 and 2).

Image below: Screenshots of the early prototype of the proposed educational software. The software runs as a web 34
application and does not require additional installation. The screenshots show the digital model of the ancient theater of Epidaurus from different perspectives (figure 3). The instructor can control the synchronized motion of the chorus shown in figure 4, or act in the middle of the stage (figure 5). Depending on the type of play, different virtual costumes and props will be available as well as different preconfigured arrangements of virtual actors on the stage. The merits of experiential learning can be demonstrated by comparing how easily the users can understand the physical size of the theater when they “walk” in the space. I would like to emphasize that all these images were screen captured from the continuous (25 frames per second) visual output of the mixed-reality program.

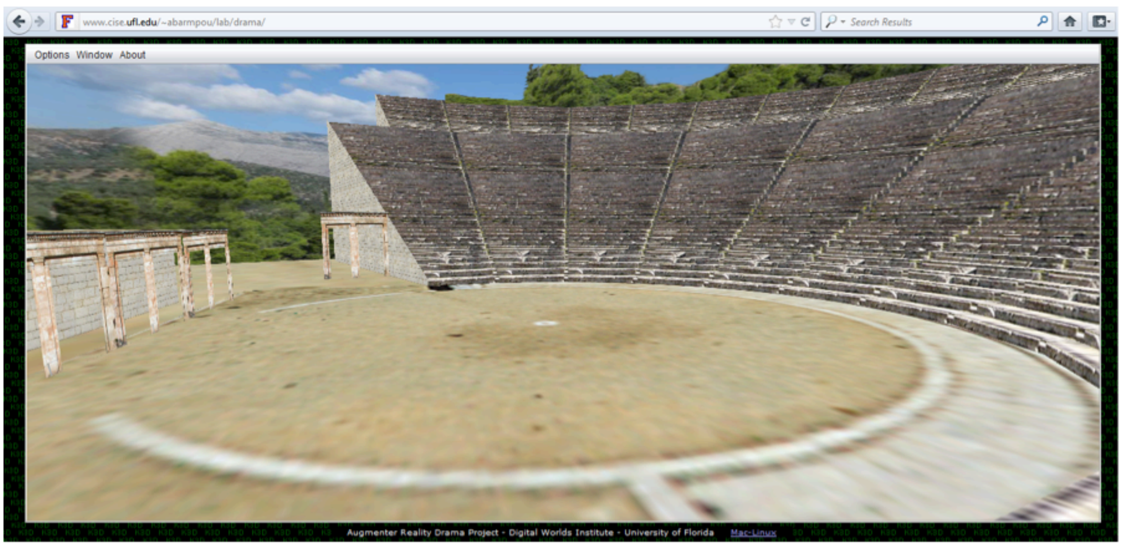

Figure 3.

Figure 4.

Figure 5.

Experimental Results

In this section I present the results of a preliminary user testing that was performed in order to quantitatively evaluate the prototype software as an educational tool. The user testing was performed with the students of an undergraduate Greek Drama class (CLT 3291) at the University of Florida in the Fall of 2013 in the regular classroom environment, in which a Kinect sensor was installed and the Magic Mirror Theater software was projected using the classroom's projector. The number of students who participated in this study was 25. Although the sample size of this preliminary test was limited, and therefore its results are not conclusive, they clearly indicate a notable increase in the students' level of comprehension. Furthermore, in order to further objectify these inferences, the initial experiments were conducted on quantifiable questions pertaining to the size and space of the ancient theater of Epidaurus. 35

The experiment was designed using photographs and a 3D model of the ancient theater of Epidaurus. The goal of the experiment was to test whether the students understand better the tridimensional structure of the theater using traditional teaching methodologies, such as photographs in a slideshow, or using the prototype interactive software. The first fundamental element of tridimensional topology that one could test is the perception of the scale, which was the key question in the test, and was also used as a metric for quantitative analysis. In general, the perception of the scale is associated with the human ability to compare the size of an unknown object with the size of a known reference, such as our own body. This relative comparison generates the perception of scale. In order to avoid any potential biasing related to the missing of a scale reference, the experiment was designed in such a way so that both modalities (i.e. the 2D images and the 3D interactive scene) had the same reference of scale, which was achieved by the presence of human bodies in both modalities. 36

The following pictures show three examples of 2D images that were shown to the students. The slide show also contained architectural floor plans of the theater. 37

Figure 6.

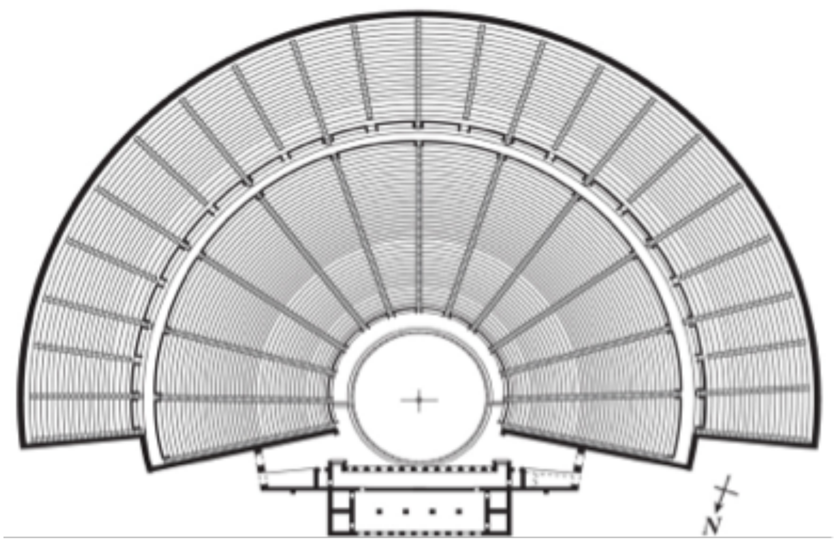

Figure 7.

Figure 8.

The first question was to estimate the diameter of the orchestra (the circular stage). This question was given to the students before the slide show, so that they would concentrate on the elements of the pictures that could help them understand the scale. After the end of the slide show, the students submitted their answers individually. It should be noted that none of the students knew the correct answer before the experiment. 38

After that, the students were asked to use the proposed mixed-reality system, and "walk" in the middle of the stage of the 3D model of the ancient theater. The students had this experience individually, and then they were asked to estimate again the diameter of the orchestra based on their mixed-reality experience. Finally, the students were asked to choose which of the two modalities was more informative in terms of determining the scale. The possible answers to this question were: a) the 2D images, b) the 3D prototype system, and c) they were equally informative. 39

The histogram of responses to the first two questions is plotted below. 40

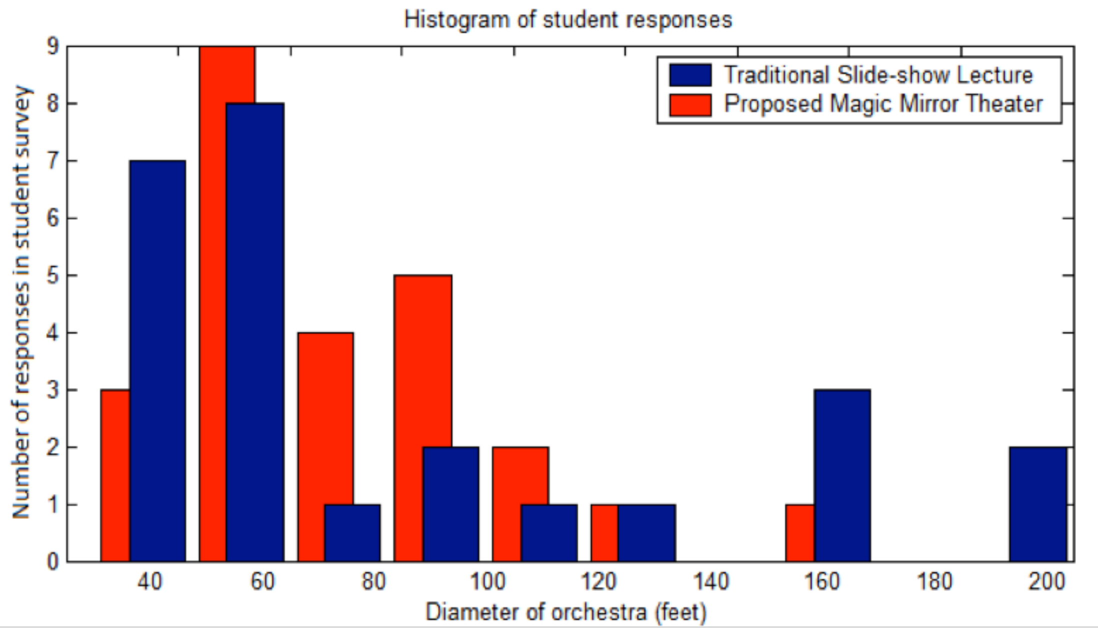

Figure 9.

A quick observation based on the above histogram is that the responses obtained using the proposed system were less scattered compared to the responses from the 2D image slide show, which suggests that the 3D interactive system increased the certainty of the students' responses. Furthermore, a larger concentration of responses around the ground truth (i.e. the correct answer, which is 66 feet) is observed in the case of the proposed system, which suggests that the 3D interactive space was more informative compared to the traditional teaching technology. These observations also agree with the quantitative evaluation that was performed in the collected data samples and is presented below. 41

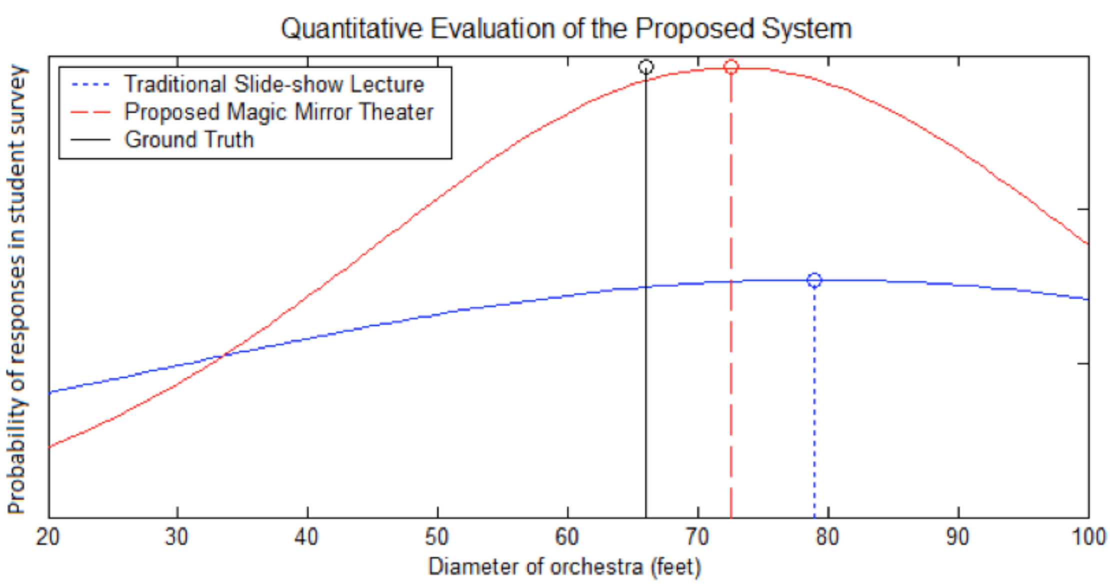

Figure 10.

A Normal (Gaussian) probability was fit to the data of each survey using the robust "gaussfit" tool in the mathematical 42 software Matlab. This tool computes the mean of the fitted probability model as well as the standard deviation (spread). The mean corresponds to the average response to each question and is depicted in the above plot as a vertical line (dotted line for the 2D slideshow case and dashed line for the 3D interactive system case). By observing the results, it is clear that the average response in the case of the proposed system is twice as close to the correct answer compared to the responses from the 2D slide show. This improvement is quantitatively evaluated using three different metrics: a) absolute mean error, b) absolute median error, and c) standard deviation, which corresponds to the certainty, and the results are presented in the following table.

	Slide-show Lecture	Proposed Method	Improvement
Absolute Mean Error	12.96 feet	6.60 feet	49.08%
Absolute Median Error	6 feet	4 feet	33.33%
Standard Deviation	51.73 feet	27.31 feet	47.20%

Table 1. Quantitative Evaluation of the Improvement in Students' Understanding

The results presented in the above table suggest that there was a 30%-50% improvement in the students' understanding of the space using the proposed system. Although these results are not conclusive because they were obtained using a small sample size, they clearly suggest an improvement in the students' perception and understanding of the space. 43

Finally, 70% of the students reported that the proposed system was more informative in terms of understanding the scale. The remaining 30% of the students reported that the two modalities were equally informative regarding the scale. However, several students from this category indicated that still the proposed system was more informative with respect to the spatial relationship of the theater with the surrounding environment and other surrounding structures. 44

	Slide-show Lecture	No Difference Noted	Proposed Method
% of responses	0%	30%	70%

Table 2. Survey on which method the students understand better the scale

Future Directions and Conclusion

In this paper the Magic Mirror Theater was presented, a web application designed to facilitate the study of Classical drama. The merits of experiential learning and virtual reality clearly suggest that in areas of research, such as archaeology and theater, spatiotemporal information is crucial for our comprehension. The Magic Mirror Theater enables the users to virtually “find” themselves in ancient theatrical venues, experience the scale, perform, use props, and ultimately be able to reconstruct the circumstances of performance in the Classical world. 45

In the future, an extended fully functioning version of this project as an HTML5 open-source software will be published. Furthermore, the project will be developed to include more theatrical venues from the ancient world so that the users may have the possibility to choose. The project will be enhanced by the addition of masks, attire, and other props and stage material, which the users will be able to select and appear to be holding on the screen. A fully functioning version of the project with the aforementioned features will allow further user testing using more complex hypotheses that will assess the long-term learning curve of the students as a semester-long experience and assessment, which is the primary future goal of this project. Finally, more advanced modalities will be incorporated, including the option to select the position of the user’s avatar in the theater as well as the usage of more than one depth sensor that will allow for more users, hence actors. 46

The scope of this project is to recreate to the highest degree possible ancient performances of Classical drama within their original space. The potential of such an undertaking would be to afford the users the opportunity to participate and better grasp the socio-cultural dynamics at play. As Weckström phrased it: “Only where the environment itself shapes 47 and is shaped by interaction that is informed by appropriate and extensive social and cultural learning can we begin to say that it is a ‘world’” [Weckström 2004].

Notes

[1] For an overview of applications in Digital Classics and Archaeology, see [Bozia et al. 2014].

[2] Scholarly interest in the reconstruction of the ancient world, including synaesthetic prototyping, has also developed. See [Foka et al. 2016] for an analysis to recreate the sonic circumstances in the Roman amphitheater.

[3] [Squire 2006] 19 also describes simulation as a process through which one “"learns through a grammar of doing and being”. For discussions on experiential learning, see [Kolb 1984] and [Kolb et al. 2000].

[4] 3D immersive and interactive teaching precepts have of course been implemented in several STEM areas. For more information, see [Cai 2013]

[5] For a discussion of virtual reality in performing arts, see [Masura 2007]. Several scholars have explored similar issues, regarding the significance of virtual reality and the preponderance of a multi-sensory study and comprehension of ancient venues and activities. See [Beacham 2012]; [Christopoulos et al. 2003]; [Christopoulos et al. 2004]; [Classen 1997]; [Favro 2006].

[6] See [Mortara et al. 2014] for a discussion of the representation of tangible and intangible heritage in serious games applications.

[7] [Champion 2015] 100-103 discusses the meaning of cultural presence and the importance of immersion in a virtual environment.

[8] See also [Champion 2015]; [Chapman 2016]; [Kee 2014].

[9] For extensive discussions on various aspects of game and historical game studies, see also [Andersen 2015], [Chapman 2016], [Gish 2010], [Kempshall 2015], [Kline 2014], [Shaw 2015].

[10] See also the discussion by [Steinkuehler et al. 2014].

[11] For the differentiation between space and place, see [Saunders et al. 2017, 1083], where the two notions are described as follows: “…place=space + meaning…Place is situated within a larger setting or space, and it cannot be understood in isolation of meaning…”

[12] For discussions of virtual archaeology, see [Betts 2011]; [Forte et al. 1997]; [Forte et al. 2006]; [Forte 2010]; [Mahony et al. 2010]; [Mahony et al. 2012].

[13] [Betts 2017] in the edited volume on sensory archaeology explores sensory studies into Roman culture.

[14] See [Kafai et al. 2014] for an extensive discussion on virtual reality’s interaction with education.

[15] For applications of virtual reality in education, see [Barmpoutis et al. 2014] and [Gee 2005].

[16] See [Gallagher 2005] and [Wilson 2002].

[17] [Milecik 2007] contends that experiential learning is inextricably linked to reality, tangiality, and virtuality.

[18] [Slaney 2017] discusses extensively the modern perception of movement in Roman pantomime through kinaesthetic approaches.

[19] For a discussion on such devices and full-body learning, see [Eisenberg et al. 2014, 342–3].

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