

# Investigating the Effectiveness of Problem-Based Learning in 3D Virtual Worlds. A Preliminary Report on the Digital Hadrian's Villa Project

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*Abstract:* This paper discusses a recent study to test the effectiveness of combining 3D virtual worlds (VWs) with Problem Based Learning (PBL) in archaeological education of undergraduate college students at two American universities. The testbed used was a virtual world of Hadrian's Villa at Tivoli (Italy), a World Heritage Site dating to the reign of Hadrian (117-138 CE). At both universities courses were offered on the villa using a PBL approach in such a way that the relative strengths and weaknesses of learning based on face-to-face, 2D, and VW presentations could be assessed. The study helped to clarify ways in which VWs can most appropriately be used as an aid to PBL.

Keywords: Problem Based Learning (PBL), virtual worlds, Hadrian's Villa

## 1. Introduction

Hadrian's Villa is the best known and best preserved of the imperial villas built in the hinterland of Rome by emperors such as Nero, Domitian, and Trajan during the first and second centuries CE. A World Heritage site, Hadrian's Villa covers at least 120 hectares and consists of ca. 30 major building complexes (for a plan, see figure 1). Hadrian built this government retreat about 20 miles east of Rome between 117, when he became emperor, and 138 CE, the year he died. The site has been explored since the 15th century and in recent decades has been the object of intense study, excavation, and conservation (for a survey of recent work, see Mari 2010).

From 2006 to 2011, with the generous support of the National Science Foundation (NSF grant # IIS-1018512) and a private sponsor, the Virtual World Heritage Laboratory created a 3D restoration model of the entire site authored in 3DS Max. From January to April 2012, Ball State University's Institute for Digital Intermedia Arts (IDIA Lab) converted the 3D model to Unity 3, a virtual world (VW) platform (Bartle 2003), so that the virtual villa could be explored interactively, be populated by avatars of members of the imperial court, and could be published on the Internet along with a related 2D website that presents the documentation undergirding the 3D model. The 3D restoration model and related VW were made in close collaboration with many of the scholars who have written the most recent

studies on the villa. Our goal was to ensure that all the reconstructed elements—from terrain, gardens, and buildings to furnishings and avatars—were evidence-based.

Once finished, the VW was used in two research projects. The first project involved use of the VW for some new archaeoastronomical studies. The VW was also used as a learning resource in two undergraduate classes offered at the University of Virginia and Xavier University. This article gives the results of the formative assessment of the effectiveness of the VW to further student learning.

Three-dimensional VWs present unique learning opportunities for students and instructors alike. Inside the VW environment students can operate an avatar in a historically accurate 3D space. The study sought to determine whether this new approach to learning was more or less effective than traditional resources (printed books, lectures, etc.) for understanding, communicating, and retaining information about complex historic sites such as Hadrian's Villa.

Specifically, the study sought to measure the effectiveness of problem-based learning (PBL) in different types of learning spaces including the new one of VWs. As students presented solutions to problem-based learning scenarios in face-to-face, 2D web, and VWs, researchers compared student and instructor perceptions of communication, knowledge ownership, and problem-solving abilities. In what way does a learning approach affect the problem-solving, knowledge retention, and communication skills of study participants? Does developing a PBL solution inside a VW deepen students' communication, knowledge retention, and problem-solving skills?

## 2. Problem-Based Learning

Problem-based learning (PBL), which originated as a strategy for training physicians in medical education (Savin-Badin and Major 2004), is a teaching and learning strategy that is problem-centered. Students in classes in which PBL is used are challenged to develop answers to ill-defined problems with many possible solutions. Instructors facilitate the

process of problem-solving. Rather than presenting facts in a lecture-style class, for example, PBL facilitators guide students in the problem-solving process, answer questions, point out helpful resources, and encourage discussion and reflection (Hmelo-Silver 2004; Hmelo-Silver and Barrows 2006). PBL is relatively new to archaeological education. The present study extends the previous work done by Kvapil 2009 while also applying VW technology to PBL for the first time.

### 2.1 Integrating PBL with VWs

The study was carried out in classroom-based courses at the University of Virginia in Charlottesville, VA and at Xavier University in Cincinnati, OH. Of the 37 students who agreed to participate in the study, all but one were full-time undergraduates. The 29 students from Xavier University were primarily freshman (17), with several sophomores (5) and juniors (5); there was one senior. The eight Virginia students ranged from freshmen to first-year graduate students. One student was a full-time graduate student in a teacher preparatory program. Altogether the study included 23 male and 14 female students; 36 students were Caucasian, and one student was African-American. All students were in their late teens to early twenties; there were no non-traditional students.

The course at Virginia was an art history seminar aimed at honors students. Achieving the learning goals of the course required the students to deepen their understanding of the art and architecture of the imperial Roman period. The class met once a week for a total of 2.5 hours. Because the class was an advanced seminar, students anticipated that independent research would be required. The course at Xavier was a Roman history and civilization course that focused on the imperial Roman period. The learning goals of the course required students to be familiar with the overall history, literature, and civilization of this period. The class met twice a week for a total of 2.5 hours. Because the course was the second in a sequence, the students expected that they would have to read ancient source material and conduct some independent research.

Since both courses dealt with similar subject matter, but originated from different departments and were aimed at a different kinds of students, the PBL component of the study was designed to find common ground between the needs of the two courses so that the appropriate content could be taught and the research goals of the study achieved.

### 2.2 Structuring PBL in the Syllabus

At the beginning of the semester, students were assigned to a team. Each week, teams researched and presented solutions to problem-based learning activities. Three of the nine solutions to PBL activities were presented in the face-to-face classroom; three were presented using a 2D web tool; and three were presented in the VW of Hadrian's villa. Specific details on each assignment were released in class and each team was given exactly one week to research and complete an assignment. Face-to-face PBL assignments required students to present their solutions using only the affordances of the face-to-face classroom environment. 2D web problems encouraged students to use a range of electronic presentation tools such as Powerpoint, Prezi, Slideshare, or Keynote to communicate their solutions. VW problems allowed students to present their solutions as avatars of their choosing inside the VW of Hadrian's Villa.

### 2.3 The Role of the PBL Facilitator

Studies have shown that one of the key success factors in implementing problem-based learning activities lies in the facilitator. A facilitator must be viewed by students as genuine, empathetic, and open to students' intellectual work (Rogers 1969). A facilitator must be able to guide students in working together in groups to arrive at their own answers to complex problems (Rogers 1983). Finally, a facilitator must be able to foster a safe learning environment, motivating students to continue to take intellectual risks in front of an audience (Heron 1989). We endeavored to minimize the differences caused by various PBL teaching approaches by having the same teacher present each PBL activities to students in both classes. The role of facilitator in both

the UVa and Xavier courses was filled by Dr. Lynne Kvapil, a scholar who had prior experience teaching PBL-centered courses and who was also the scheduled instructor of the Roman history and civilization course at Xavier. Dr. Bernard Frischer, a professor of Classics and Art History at Virginia and principal investigator of the research study, co-taught the course offered at the University of Virginia.

### 2.4 Problem-based Learning Materials

The students of both classes had access to a rich cache of resources for researching solutions to the PBL problems. These were made available on the Blackboard course site and through online resources including JSTOR and ARTstor. In addition, a number of print and digital resources were made available to students. Books about Hadrian's Villa as well as Roman art, architecture, and history were put on reserve at the UVa Fine Arts Library and at the University of Cincinnati John Miller Burnam Classical Library.

### 3. Technology

The process of simulating the villa site of Hadrian was a significant interdisciplinary effort involving an international team of scholars, educators, designers, artists and technicians. Ball State University's Institute for Digital Intermedia Arts (IDIA Lab) produced the multi-user avatar based VW of the villa employing custom middleware that leveraged the game engine of Unity 3 (figure 2). A primary goal of the project was to create environments that were both accessible and straightforward enough to engage first time users of VWs. The immersive learning environment could be experienced by using either installed executable versions and or from standard web browsers running on Windows or Macintosh operating systems. The back end administrative management relied on Smart Fox Server for creating accounts and regulating the 3D environment. The immersive environment was created through the integration and deployment of commercial products and custom software developed specifically for the project. The feature set available to students consisted of typed chat, a dynamic map displaying current visitor locations, online user status, teleportation via a

map interface, multi-user voice channels, a triggerable avatar gesture system, layers of paradata, plan views, panoramas and site photographs, and integrated in-world URL links.

Visitors to the simulation entered the world by means of a custom avatar system designed specifically for the project. A user could select from a variety of avatars representing class, gender and ethnicity including the imperial court, senators, scholars, freemen, soldiers, and slaves. The avatar system was based on scholarly studies of circulation and flow throughout the villa. Avatars also served to populate the various places in the villa used for the daily activities of the court, including imperial audiences, dining, bathing, and worship. A visitor's choice of avatar informed his social standing within the role-play of the simulation. A custom gesture system was created through motion capture and hand animation to provide the student with a unique set of actions and gestural responses specific to his chosen avatar. Gestures included greeting, affection, and supplication that varied in implementation according to the particular rank and class of an avatar. Communication technologies included public typed chat, private typed instant messaging and live group or private voice channels.

Integral to the project was the development of a companion web site for the VW of Hadrian's Villa that provided learners with visual assets and written information about the state of the villa site today (figure 3). The visual assets include site plans, photographs, elevations, 3D models and panoramas of the archaeological park. The web site also provides descriptions and function of each villa feature and makes available scholarly interviews with prominent villa scholars. The web site offers paradata—a concept introduced by the London Charter ([www.londoncharter.org/glossary.html](http://www.londoncharter.org/glossary.html)—making transparent the scholarship and methodologies of the reconstructions (from terrain to buildings, furnishing, clothing, and social protocols, etc.). All assets and information can be accessed by students directly from either the virtual simulation or from the web site itself.

#### 4. Data Collection and Analysis Method

A review of literature from medical schools and universities shows that a purely qualitative or quantitative form of assessment may fail to capture the added benefits experienced by students in PBL classes. Given that PBL activities have been found to improve not only a student's knowledge of content but also higher-order thinking skills—skills often considered more difficult to assess—we developed a mixed methodology for collecting instructor and student perceptions of known PBL outcomes (cf. Barr and Tagg 1995; Ewell 1997).

Different forms of individual and group assessment were used to learn more about both group skills and individual knowledge. In general, assessment served as a learning tool given that three types of assessment were levied (cf. Earl 2003): assessment of learning (i.e., summative traditional tests—learn from a grade); assessment as learning (i.e., formative blogs—learn while participating in blogging activity); and assessment for learning (i.e., peer assessment rubrics—learn through feedback).

#### 5. Preliminary Study Results

##### 5.1 Observations of PBLs in Learning Environments

Each PBL activity required the students to solve a problem relating to the emperor Hadrian and life at his villa. For example, in the activity titled “Heads and Tails” students imagined they were officials in Hadrian's governmental department that produced and distributed imperial coins. As members of this department, they were asked to design a coin that would promote him as emperor and reflect the values that inspired his construction of the villa. Students' solutions to each PBL activity were presented in class to their peers and to the instructors one week after the activity was assigned. Each week, the instructors assessed student presentations and recorded observations. Assessment of the presentations focused on how students took advantage of each learning environment; whether students considered the impact and feasibility of their solutions; the perception of time, space, and structure in relation to the villa, and how well students could integrate prior knowledge with new knowledge in their presentations.

Changes in the way students considered time, space, and structure in the villa were most noticeable after students had been introduced to the VW because they had experience moving their avatars around the virtual space, and they had access to a date and time slider. Prior to that time, students were observed discussing buildings and their spatial relationships based on a traditional map of the villa. After students had access to the VW, they discussed not only buildings but movement through the spaces between buildings, and they gave their classmates directions based on surrounding structures and visual cues including corridors, staircases, statues, fountains, and other features that are difficult to visualize when reading from an architectural plan.

## 5.2 Formative Assessment/Blogs

Throughout the semester, students posted answers to formative assessment questions revolving around themes of communication, knowledge retention, and problem-solving skills.

When students were asked what surprised them the most about the VW, one blogged: "while in the VW when working on the PSAs with Maria (name changed), I am astounded by the graphics and the level of detail for each building. The VW has really helped me to understand the layout of the Hadrian's Villa and what the buildings actually looked like. I feel like I have also finally gotten a grasp, especially after this specific problem-solving activity, on how to navigate Hadrian's Villa and determine what routes you can actually take. The level of detail of the characters as well as the surrounding environment is also incredible. I also like how you can change the date and time settings, which is useful when picking a specific day for our PSA solutions. Ideally, more statues and art will be added" (Blog response, April 23, 2012). Another student blogged, "I find it amazing that the 3D world is shaped upon archaeologically supported details, and it makes me feel as though I am navigating in the past" (Blog response, April 30, 2012).

## 5.3 Focus Group Interviews

At the end of the term, student groups participated in topic-based, focus group interviews. A total of nine focus group interviews were conducted at both universities by educational researcher Dr. Lee Taylor-Nelms. Throughout the interviews, students stated that the concept of PBL and group work, in general, was not often used in other classes they had taken. They were more familiar with the traditional teaching construct of lecture, tests, and papers. The very idea that a PBL environment may not result in a single "right" answer proved unsettling for some. Several groups mentioned that the workload for this class was higher than that they had experienced in other courses.

When asked to compare differences in 2D, VW, and face-to-face PBL activities, students often commented on the spatial benefits of the VW. Although all students received a printed map of Hadrian's villa, the ability to navigate inside the reconstructed buildings in the VW gave them a different perspective on how historical events might occur. In addition, since the VW did not permit avatars to fly, walking around the villa as an avatar gave them a better appreciation of the scale and dimensions of the villa. "It took a long time to get anywhere," one student commented (Student interview, May 1, 2012). The presence of non-player avatars (avatars not controlled by humans) also gave students a better sense of how the space worked. It made them ask questions that may not have occurred to them otherwise such as: "How many groundskeepers did it take to run Hadrian's villa?" (Student interview, May 1, 2012). Several groups mentioned that they were able to control the positioning of the sun inside the VW space. This control allowed them to see how the space looked at specific points in time and proved beneficial in better understanding the interrelationship of culture, religion, and architecture.

Several groups noted the similarities in the face-to-face and VW PBL activities because required more group collaboration than did the 2D activities. Although instructors did not prescribe how to deliver presentations, students interpreted face-to-face and VW learning environments as exercises where role-playing was appropriate or even expected. Some groups mentioned that not all activities

lent themselves easily to role-playing solutions. In those cases, students found a face-to-face or VW solution to be limiting. Other groups described role-playing solutions as enlightening because they offered a new perspective on a problem. "By re-enacting a solution, we could actually see what worked and what didn't," one student remarked (Student interview, April 30, 2012). Many noted the biggest difference between VW and face-to-face activities was the opportunity to bring physical objects into role-playing scenarios. In some face-to-face presentations, students dressed in traditional Roman garb or prepared food for a feast. Although it is technically feasible to dress an avatar or to arrange for a virtual feast inside the VW, creating objects and altering an avatar's dress is not an available option in the current version of the VW of Hadrian's villa.

Almost every group mentioned that face-to-face and VW PBL solutions took longer to prepare and present than did the 2D presentations. The reason was that groups felt they needed to coordinate and practice their "parts" with other group members. In contrast, with 2D slide presentations, the groups felt they could simply break the presentation down into discrete sets of slides on the various topics to be covered, and give each student in the group the responsibility to create and present a given set of slides. Presentation time of VW and face-to-face activities often took longer because students felt 2D slide shows allowed them to use bulleted points or images to express multiple solutions to problem, whereas VW and face-to-face solutions required explicit, verbal expression.

#### 5.4 End of Semester Instructor/Student Surveys

End-of-term instructor surveys saw student success as based on understanding ideas more than memorizing facts. In addition, instructors thought students found the VW engaging and motivated them to spend more time exploring the VW and the resources in it. Instructors agreed that learning how to use the new VW resource and dealing with inevitable technical difficulties diverted some attention from academic tasks. However, by the end of the course, they believed that their observations of student PBL solutions in VWs attested new

ways in which students thought differently about issues such as space, time, and structure.

End-of-semester student surveys asked students to respond to similar questions posed to instructors. However, it was clear that student perceptions on the effectiveness of the VW environment was more influenced by some of the technical difficulties many experienced in using the VW. Despite the difficulties, both instructors and students "extremely agreed" that the scholarly team should continue to keep improving and extending the Unity 3 application. One student wrote: "the 3D world has *potential* and it can grow into something if it is explored and more options are given to students who actually desire to *make* it work. All ideas have to be listened to and explored. It requires a teacher and a student to experiment with it and find out new creative ways to use it outside of its intentions."

#### 6. Conclusion

PBL activities presented new challenges for many students at the two universities. For most students, the learning environments in which PBL activities were presented proved less challenging than the concept of PBL itself. The very notion that a problem could result in multiple solutions and that students could learn from each other struck some students as downright antithetical to pedagogy in the humanities. Despite the fact that PBL has long been in use in other fields, PBL struck many students (especially those not majoring in Education) as a new and experimental approach to learning. When asked, students often reported that with the exception of science labs, most of their college classes did not require group work and classroom presentations. Their typical classroom experience had consisted of lectures, tests, papers, and quizzes.

Thus, it is not surprising that when asked to be creative and take advantage of the unique affordances of each learning space, most students lectured. With encouragement from the PBL facilitator, groups began to role-play and write skits rather than to deliver reports. Some groups even dressed up and brought in props like food to make their role-play more authentic and meaningful, but most did not

question the primary delivery mode which was (in more cases than not) an oral delivery. Students could have used space as a catapult to present information in creative formats but often they did not choose to do so, in part because of the limitations presented by the infrastructure of the classroom. In one face-to-face presentation, a group used the desks in the classroom to simulate the layout of a Roman banquet, but more frequently students seemed to feel constrained by the traditional classroom layout.

2D presentations were similar in that students reported what they knew with the help of visuals. Being able to use Powerpoint or Prezi as a visual organizing tool seemed to help some groups to communicate information more effectively. In most cases, students noted 2D presentations were easier to follow because the information was clearer and easier to understand. It also seemed to help groups in managing work flow virtually without the added pressure of finding time for face-to-face meetings. Also, 2D presentations seemed to offer a familiar, comfortable format for most students. In effect, when asked to give a 2D presentation, students felt they were playing the role usually filled by their professors.

The VW proved the challenging for some students because it required them to be creative in ways traditional classroom formats do not. Given that the VW resource was designed to function best as a tool for spatial navigation, it greatly facilitated archaeological problem-solving, allowing students to develop a spatial understanding and appreciation of problems set in ancient times. As beneficial and unique as this benefit is, this single feature did not always result in superior communication or knowledge retention than did the more familiar formats of 2D slide shows or face-to-face presentations. To some extent this may be attributed to the trepidation students felt toward unfamiliar technology. More experience with VW technology and role-playing via avatars might encourage more creative solutions while giving students the opportunity to have the experience of operating in an ancient environment.

In terms of formative evaluation of the digital resources created to support the educational research, both students and instructors agreed

that the VW needs additional improvements to become fully functional in promoting the PBL goals of communication, problem-solving, and knowledge retention. Specifically, students felt the following features would greatly enhance the value of the VW for learning:

- Enable students to switch between avatars without having to open/re-start the program
- Add an orientation map in the villa so it is clear where you are at all times
- Add a sound signal over avatars so it is clear who is talking when
- Add the ability to switch the view of an avatar from 1st to third person
- Add the ability to zoom out from your avatar and focus in on other aspects of the world
- Put the avatar name above the avatar so others know who is who
- Allow students to click and receive information on avatars (bio, clothes, animations)
- Permit multiple avatars (controlled by students) in-world without technical problems
- Allow objects to be picked up and include metadata about those objects
- Develop realistic animations with non-player characters (NPC), e.g., avatars stab a NPC, who reacts
- Include information about NPCs when clicked
- Allow avatars to move faster i.e., to jog, run, or walk faster
- Allow avatars to build objects, e.g., to create a banquet
- Permit customization of avatars i.e., dress, animations, and gestures.

The IDIA Lab will be taking advantage of the testing of the VW reported here in order to make improvements for the next release, which is scheduled for the fourth quarter of 2012. In fall 2012 and spring 2013, this version will be tested in courses taught at the University of Virginia and Xavier University.

The main lesson learned thus far is to confirm that PBL can be effectively used in archaeological education, albeit in a new way. In the past, PBL has been used to put students in the role of the contemporary archaeologist researching ancient material (Kvapil 2009). In

the present study, PBL promoted learning by putting students into the role of ancient people.

At this time, the communication capabilities of the Hadrian's Villa VW are limited compared to a face-to-face presentation environment in which students can convey information non-verbally by displaying objects, changing one's dress, and re-inventing a scene. The VW, as currently designed, is also fixed and limited to oral expression through voice or text. From the learner's perspective, solutions presented in the VW may have been more difficult to follow given that solutions could only be expressed within a pre-staged environment without alterations. Learners found a 2D presentation easier to understand as it allowed students to share information visually (through pictures/symbols), and reinforced key oral information in bulleted points, but this viewpoint also reflects the expectations of students who had much greater familiarity with traditional class structure and the technology that accompanies most art and archaeology courses. Students found 2D and face-to-face environments more effective in communicating and hence, understanding and retaining knowledge in the long-term. But the richness of the VW environment of Hadrian's Villa provides a new opportunity for students to explore and master complex Roman architectural spaces and to participate first-hand in the functioning of ancient society in ways that cannot be replicated even if each student had the opportunity to visit ruins of Hadrian's Villa.

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