Immersing in Mesopotamia
Virtual Reality Site Tours in the Remote Classroom

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Student Charmaine Mak using the VR headset at home.

Virtual Reality (VR) holds the potential to improve student spatial and visual learning in archaeology through embodied 3D interaction with ancient spaces and objects. For an introductory course on Mesopotamian archaeology that spanned the Uruk to Achaemenid periods, we experimented with VR tours as part of the student learning experience. Although there are many publications covering the use of VR for cultural heritage/public history or for teaching in other fields, examples from the archaeological classroom are limited. To get a sense of what is possible for archaeological learning today, we undertook a rapid pilot experiment to prepare ourselves for future, more structured, educational research. This pilot helped us to explore the logistical concerns of deploying VR in an undergraduate course. We also interviewed the students several months after the course to hear about their experiences with VR learning. We share our experiences here to encourage other experiments with VR teaching in the archaeological classroom.

Although the logistics and student experiences were our main focus, it is useful to conceptualize archaeological pedagogy within a broader educational theoretical framework. Digitally mediated pedagogy is a proliferating field, particularly when it comes to training students on how to use digital tools that simulate authentic experiences for their future profession (Nieminen, Bearman, and Ajjawi 2022). Virtual Reality teaching has received attention recently in multiple other disciplines (Kumar et al. 2021). In their systematic study of VR in education, Jazier Radianti and colleagues (2020), note that we need to focus on learning outcomes when testing VR and we need to find ways to make VR teaching a natural component of normal coursework. Sam Kavanagh and colleagues (2017) also point out that VR has not yet seen widespread adoption in teaching given the logistical and financial challenges of implementation. They found that many experiments with VR are aimed at increasing student motivation for learning, but they see potential to address other areas with new technologies. Remote learning has also been the subject of much attention in recent years (Looi, Wye, and Abdul Bahri 2022).

Archaeologists have long considered if digital media change how we interact with our information and learning (Morgan and Wright 2018; Liang 2021). The theories related to embodied, experiential, and authentic learning seem to be particularly valuable for archaeology. Embodied learning directly links our motion in the world and our tactile interface with objects to our ability to learn any subject more deeply (Kiefer and Trumpp 2012). Experiential learning removes pedagogy from the controlled environment of the classroom to challenge learners' beliefs and force them to adapt (Kolb 2014). Traditionally, fieldwork has provided an ideal environment for embodied experiential learning, but we all recognize the deep challenges with fieldwork accessibility (Heath-Stout and Hannigan 2020; Cobb, Cobb, and Azizbekyan 2022). Although it may never be a perfect substitute for real-world experience, perhaps VR could provide at least some surrogate for aspects of embodied experiential learning in archaeology to students. In this way, VR technologies may also promote inclusion and equity by widening access to archaeological sites to students who, for various reasons, cannot visit the physical sites. We see VR as specifically enhancing spatial and visual learning about the objects, architecture, sites, and landscapes of the past. As the students move around in the immersive environments, they can learn about ancient spaces in ways that are not normally conveyed through 2D lecture slides and readings.

In our Mesopotamian archaeology course, we took the students on VR tours of four sites, each partially reconstructed either in their excavated state or to reflect an ancient period. We built our own 3D models of areas or buildings at each site, which was the most resource-intensive part of our experiment. There were seventeen students enrolled in the course plus two auditors, though two students did not have access to VR devices. Although we had already intended to experiment with VR, our university moved to remote teaching early in spring 2022, giving us a new impetus to provide an opportunity for embodied interactions with the students in ways not enabled by videoconferencing. Our experience with this pilot experiment, which we share here, has informed us about how to structure such VR teaching in the future. Ultimately, we all need to try new things, whether they work or not, in order to learn and think through what we shall try next (Graham 2022).

Technological Opportunity

Several recent studies have experimented with teaching archaeology using non-VR digital 3D models (Haselberger and Holzman 2015; Garstki, Larkee, and LaDisa 2019; Derudas and Berggren 2021). We hope to extend these positive experiences further by deploying VR headsets for interaction with 3D archaeological models. We take advantage of the recent developments in VR hardware by various companies. Our university lent Oculus Quest 2 devices to the students for use in their own homes (see banner image). This is a wireless headset, so users do not need to have a powerful laptop to use the device and they can move freely without becoming entangled in a cord. It also has a high screen resolution of 1920 x

Workflow for Creating 3D Archaeological Site Models

1. Identify a site that has appropriate publications.
2. Construct a topographic surface by exporting topographic map image to 3D software, scaling image, tracing and raising contour lines, and building a polygonal surface over the contours.
3. Identify sections of the site with sufficient data for 3D modeling.
4. Export 2D plans of excavated architecture as images, import into 3D software along the x-y plane and scale images.
5. Trace walls and extrude walls into 3D models, following text descriptions and photographs to simulate excavated state.
6. Cut the topographic surface above the excavated areas and connect these models.
7. If undertaking the reconstruction of ancient buildings, follow text descriptions and find comparanda from nearby sites to add walls, windows, and roofs.
8. Locate textures from the Internet based on photographs and text descriptions, apply to models.
9. Send model draft to archaeologists and iterate to improve.

Figure 1. Browser view of Spatial.io tour of Chogha Zanbil, with default inaccurate distant landscape.

Figure 2. Touring the Ubaid temple at Tell Abu Shahrein.

Figure 3. Touring Umm al-Aqarib, with sky directional cross visible.

1832 pixels in each eye, better than many other devices on the market (https://developer.oculus.com/resources/oculus-device-specs/). The shelf-price was $299 for the version with 128GB of storage, so it was relatively affordable when we used it, though the price has since increased to $399. It comes with two hand controllers and has built-in spatial awareness of its surroundings without separate external cameras. Given the pace of development, we anticipate that future devices from multiple companies will rapidly improve on this current option.

We needed a way to enable multiple people remotely to tour the 3D site models at the same time from their own VR headset, while viewing each other as digital avatars. We experimented with custom software built by engineers at our university and Mozilla Hubs, but found Spatial.io most suitable. In Spatial.io, we could place models into separate named "spaces," so we loaded each site model into its own space. Each avatar can be individually customized by the user, including the ability to place a personal photograph onto the face of the avatar. The software provides basic navigation in the virtual space with teleporting (jumping) or walking functions using the hand controllers, which also enable visible hand gestures, and the software supports remote audio communication. However, we faced several challenges. First, there are limitations on the size and complexity of the models that can be loaded. Second, we had to convert 3D file formats, usually with Blender, to load mesh models

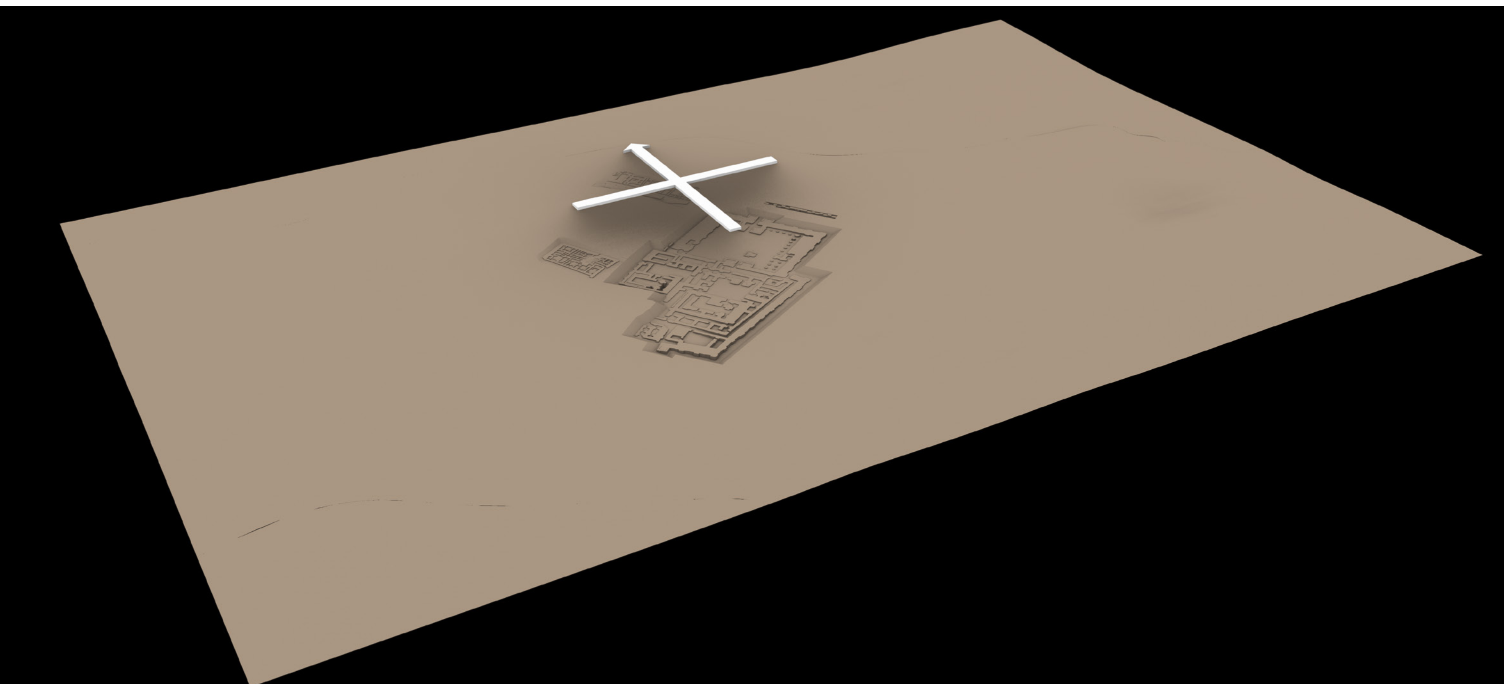

Figure 4. Terrain model of Umm al-Aqarib, with some sections reconstructed, and the sky cross with north arrow.

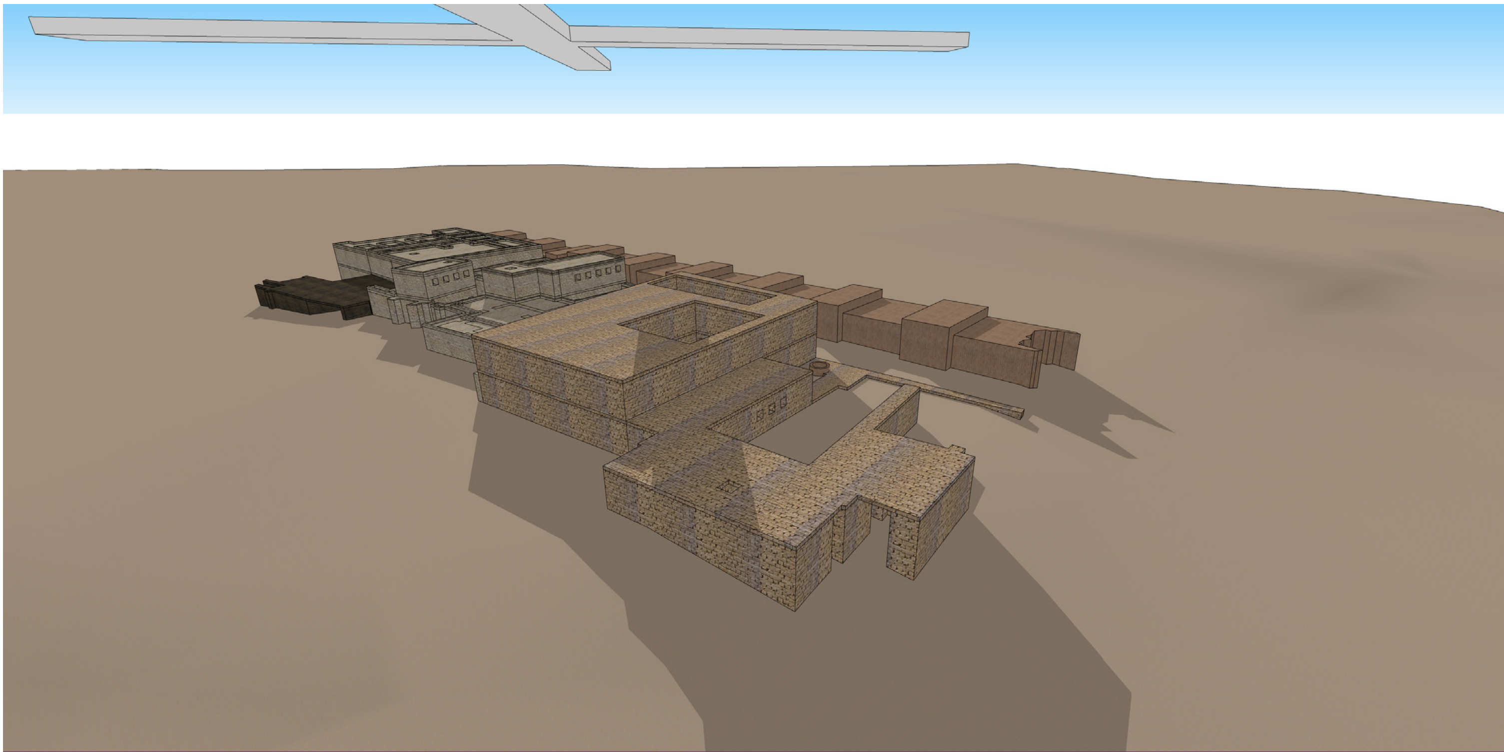

Figure 5. Reconstruction of buildings at Umm al-Aqarib.

in the .glb or .fbx formats. Third, we struggled to get the models to look 1:1 full scale in our first attempts. Finally, our Mesopotamian sites were surrounded by the default forested hillscapes (fig. 1). We wanted to replace this scene using a 360-degree photograph in a sphere (called a skybox), but it was not large enough to fit our model inside.

We split the class into two groups of about nine students and met for an hour each week to tour one or two of the sites (fig. 2). We all met in the Spatial.io virtual environment, with the avatars starting from the same place. The instructor led the tour over an audio channel, beginning from a high point in the terrain to give a general description of the site, its history, and the surrounding landscape (fig. 3). Using the two hand controllers, the instructor could point to features. To help guide the students, we added a large white cross hovering in the sky, with an arrow on the branch pointing north (fig. 4), so we could speak in cardinal directions. Next, the instructor led the students to individual features or buildings throughout the landscape, sometimes asking the students for their initial observations and then describing the feature by moving around and pointing to various aspects. Students could also freely wander through the structures themselves. When the tour was finished, the instructor asked the students for their questions and observations about the site. Students raised their virtual hands using their controller, and then unmuted themselves to speak to the group.

Building the Models

Our primary goal in building the 3D models was faithfully to represent the spatial layout of selected remains on each site so that students could bodily interact with them, rather than to make perfect ancient models. We also reproduced some local topography so that students could get a feel for the landscape context. We employed four current and recent architectural students, both undergraduate and master's, to work as our modelers, since they already have the necessary software skills. We also hired an undergraduate humanities student to manage the process and provide archaeological data to the modelers, as well as an undergraduate student from the statistics department to help us set up the technology and troubleshoot problems. The modelers did the best they could with the limited available evidence formatted as articles or books—not ideal for conveying detailed 3D space. We modeled only the parts of each site with the most evidence, often public buildings that were the main foci of the excavators.

We modeled parts of four sites: Tell Abu Shahrein/ancient Eridu, Umm al-Aqarib/perhaps ancient Umma, Chogha Zanbil, and a site currently under excavation in Armenia. Our modeling steps are summarized in the sidebar. We sought out sites with published evidence, but without current 3D modeling projects. For Tell Abu Shahrein, we used the report by Fuad Safar, Mohammed Ali Mustafa, and Seton Lloyd (1981) about their 1946–1949 excavation. This has photographs and ground plans of the Ur III ziggurat, Ubaid temple, and Uruk portico building. We also reviewed prior and recent publications for further information (Van Buren 1948; Ramazzotti 2015). For Umm al-Aqarib, we relied on Haidar Almamori's articles covering excavation work in the 2000s (2014a, 2014b). For Chogha Zanbil, we looked through sources about the site's main ziggurat and sanctuary (Ghirshman 1966; Mofidi-Nasrabadi 2004, 2015). For the fourth site, we

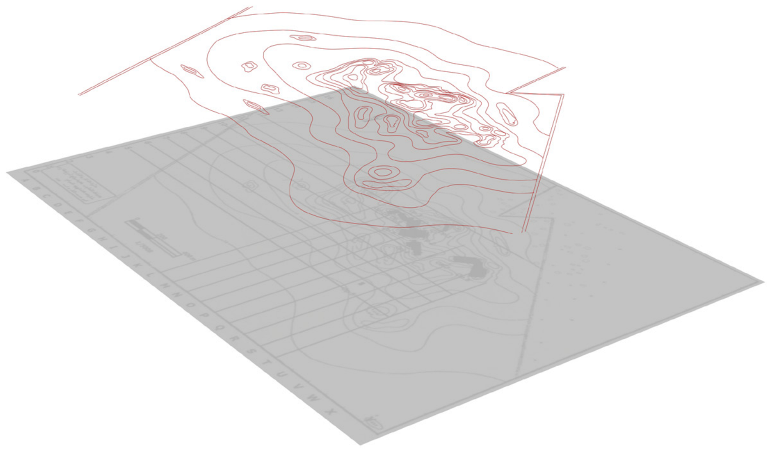

Figure 6. 2D plan plus the traced contour lines of Umm al-Aqarib.

reconstructed architecture based upon drone-acquired photogrammetric terrain data from an ongoing excavation based on surface-visible features.

One architecture master's student built a model of the excavated remains of several areas of Umm al-Aqarib (fig. 4). She also reconstructed several buildings within one excavation operation to simulate how it may have looked in the Early Dynastic (ED) period (fig. 5). Each raster map or plan from Almamori (2014a) was individually exported from the article and brought into Rhino3D to be placed on a flat rectangular polygon in the x-y plane. She adjusted each image to the correct scale, so that one meter's length on the embedded raster scale bar became one unit within Rhino3D. A regional topographic map provided one-meter contour lines between about seven and seventeen meters in elevation, across an area of roughly two kilometers on each side (Almamori 2014a: 154, fig. 6). The modeler built a terrain model from this map by tracing the contours as curves in Rhino3D and setting their heights relative to each other (fig. 6).

She then made models of the excavated state of the sanctuary area (Almamori 2014a: 164, fig. 22), the palace (179, fig. 48), and the production buildings in operation 1 (158, fig. 11). She traced the layout of each building, and then raised these walls to an approximation of their preserved height based on the combined evidence of the views in excavation photographs as well as the textual descriptions. She placed these excavated areas under the terrain model, at an approximate depth of excavation. She then cut out the terrain model above each of these areas and connected the two models with sloped edges (fig. 7), approximating the excavation trenches. The modeler found this process to be challenging, since the topographic model had to be carefully manually edited in multiple places.

To make the buildings and landscapes appear somewhat realistic, she placed digital images as textures onto each model's surfaces. In general, this followed an expedient path to complete the models quickly. Using the color photographs from the publications as a guide, she did Google Image searches to match how she felt the land and buildings would look. We hope to find only open access images in the future.

Our modelers had a learning curve for working with archaeological data and they worked remotely. On average, they reported spending about 150 hours on the model of each site. Since modelers used whichever software they were most familiar with, they had their own licenses (fig. 8). Our project already had a thirty-user floating network license for Rhino3D, which had cost about $1000 with the educational discount. One of the students also used SketchUp Pro, which costs $55 for an annual educational subscription. Our statistics student used the free Blender software to convert files.

We advocate for the archaeological community to come together to provide 3D data to each other. Excavators know their site best and have access to digital data products that are now often created with drones, photogrammetry, lidar, and 3D modeling software. We suggest that researchers should therefore publish their site's raw 3D data in open access venues for others to use (Kansa 2012). Our interpretations of past spaces are central to our normal publications, so we also hope that others will begin to publish these interpretations as 3D models (Opitz 2018). It would be ideal if such products would be recognized by tenure committees for the valuable intellectual contributions they are (Ebeling and Caraher 2022). As for historical excavations, we shall need to work with what we have in terms of published or archival data from the last two centuries, therefore, as an example, we provide our models through the Github platform (https://github.com/anatolian/mesopotamia-3d-site-models). Hopefully others will edit and improve our models and share them again.

Student Reactions

To understand the potential of VR learning and plan for more comprehensive future experiments, we interviewed students about our pilot use of VR in this course. We asked questions that considered their spatial and visual learning. To probe their memories, we spoke to the students four months after the end of the course. We interviewed seven of the seventeen students who had used the VR headsets for most of the tours. These interviews took place over videoconferencing software and were recorded, and students received a small financial renumeration. We acquired human research ethics approval from our university (HREC reference number EA210522). We undertook a detailed reading of the transcripts of the interviews to identify some trends.

In the interviews, we first asked the students to identify from memory, by name or by recognizable description, any of the archaeological sites we had taught about in the course. We observed some patterns among the students about what they could recall after four months from among the twenty-one sites we lectured about and the other four sites we introduced in VR. The number of students who remembered each site were, from VR: Tell Abu Shahrein (four), Armenia (four), Umm al-Aqarib (two), Chogha Zanbil (one); from other media: Ur (five), Kültepe-Kanesh (five),

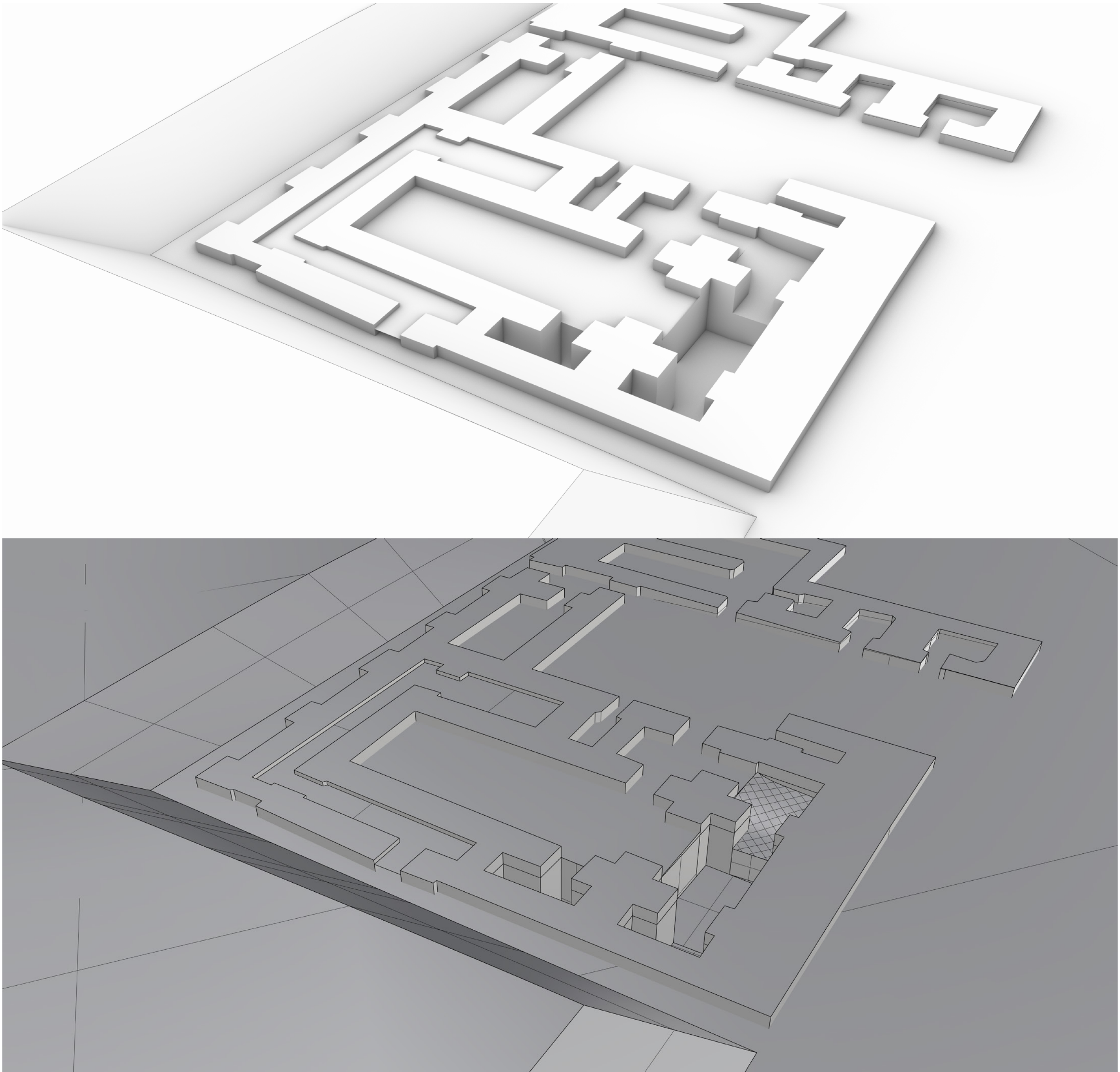

Figure 7. Solid (top) and wireframe (bottom) views of the excavated-state of building remains at Umm al-Aqarib.

Yazılıkaya (three), Assur (one), Babylon (one). Included in these results are our follow-up questions prompting them to remember additional sites after their initial recollections. When we asked the four students who had not initially recalled any VR sites if they could remember anything from VR, three of them each remembered one site, Chogha Zanbil, Tell Abu Shahrein, and Umm al-Aqarib, while the fourth student could not recall any specific site from VR. When we prompted the one student who had not recalled any sites from non-VR teaching, she still could not recall any further sites.

During the recall process, students often described VR sites by spatial or visual characteristics, whereas they described the sites learned from other sources by a mix of characteristics, often foregrounding the sociocultural instead. For example, without being able to name Tell Abu Shahrein, Student 1 first recalled that "the site is quite large" and that the instructor had shown them "some walls at a corner," referring to the Ubaid temple, and later she associated that area with religious activities. Student 2 similarly remembered that "in the corner of the new temple, there is an old one." In recalling Umm al-Aqarib, Student 3 made the following observations: "there are separate

Figure 8. The modeler Luke Zuye Li working on Tell Abu Shahrein in Rhino3D.

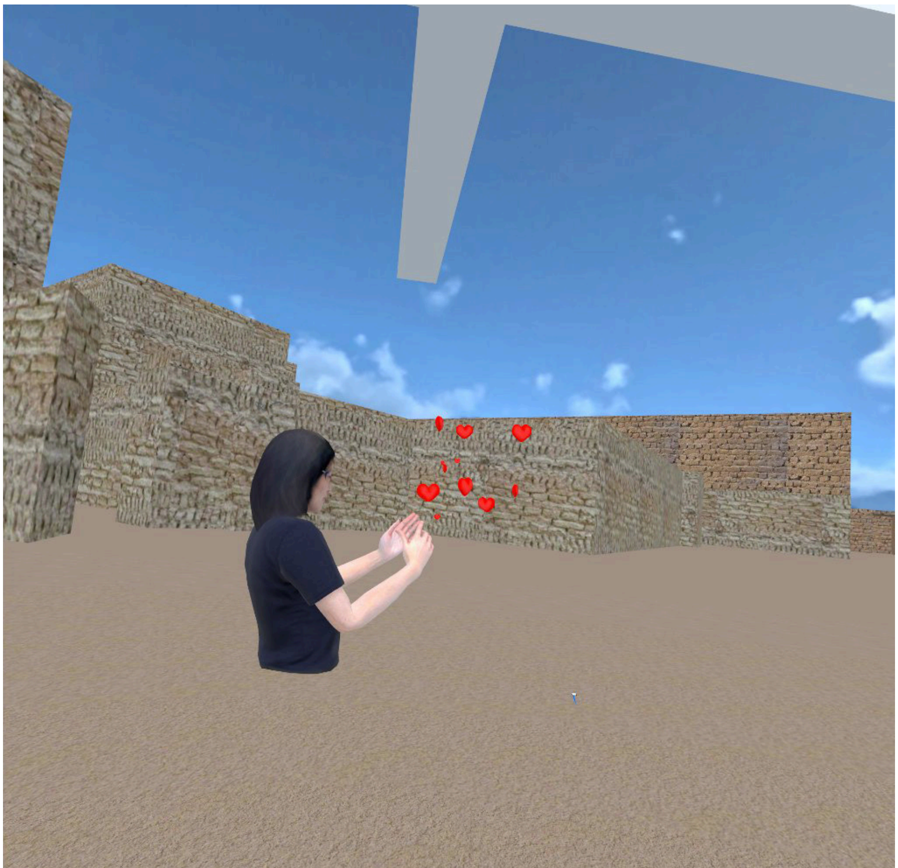

Figure 9. Student avatar clapping in Spatial.io.

buildings, I remember we visited like 2 to 3, but they are all ruins, with only walls, the foundations of the walls … they are pretty close because we can kind of walk in that space, and we can just walk there on foot." Student 6 remembered the reconstructed Tell Abu Shahrein model through motion and visual aspects, saying "I jumped into a particular place where there was some sort of statue," referring to the Ur III period ziggurat. Student 7 remembered that the reconstructed structure at Chogha Zanbil had many levels and that she needed to walk up staircases to get to the top. Student 1 specifically mentioned the VR tour of the site in Armenia "because I remember the steepness of the slope." Other students also pointed to other aspects of space, motion, or visual cues in their recollections of the VR sites.

On the other hand, most students remembered the non-VR sites based on more diverse characteristics. For example, the main recollection about the Royal Cemetery at Ur was about the human attendants buried in the tombs, as Student 6 mentioned: "there's a lot of discussion on whether it was for sacrifice or whether they were willing to [be there] voluntarily." For Kültepe-Kanesh, many of the students were interested in the gender history highlighted in Old Assyrian documents like marriage contracts, and Student 5 recalled that "women were … involved a lot in trade," which she thought was something we had not seen with other cultures. Spatially, students did also recall the separation between the high mound where the locals lived from the trading colony on the plain. For Yazılıkaya, students remembered that it was associated with rituals involving both the underworld and sky deities. However, this site also was remembered for its geography and relief sculptures, with Student 4 recalling it as "the one that is on the mountain and there … [are] astronomical features … [related to] life and death."

We were also interested in seeing if VR would improve their ability to understand and describe the spatial characteristics of the sites. We asked them if they could explain the spatial layout of each site they remembered, both from VR and non-VR learning, as if they were telling someone who was about to visit the site how they should move around. The accounts in the interviews were mixed, as students had a range of answers. For example, in terms of non-VR, Student

6 remembered that there were funerary objects and servants nearby to the main burials at the cemetery at Ur, but then said: “for specifics of the building, like the size and that, I don’t quite remember.” Student 4 remembered that there were two separate spaces at Yazılıkaya and that there were figures on the wall. Interestingly, she also remembered the following detail about Kültepe-Kanesh: “the rooms are actually quite small, I think … there’s only a room for cooking and then another room for living. So it’s comparably smaller than the houses in the bigger city with the wall.” For VR, Student 3 seemed to be remembering the palace at Umm al-Aqarib when she observed that it “still has the division of rooms, like spaces, and you can still identify which room serves what particular functions.” Student 2 was able to remember that the Ubaid temple at Tell Abu Shahrein was located on the southeast corner of the newer Ur III ziggurat, and noted that “further, there’s a city wall, but it’s mostly ruins, so not that clear at all.” For non-VR, he also recalled that Assur was “kind of like a semi-peninsula that the river is … curved around the city” and that Babylon was on two sides of a river with a rectangular city wall. Student 2 was unique for being the only student to actually remember these two sites, and self-assessed his spatial skills as relatively high.

Since this was a remote course, students lacked other opportunities to interact in embodied ways, as their main contact occurred through the videoconferenced lectures. Although the VR experience was a tour where the students mostly listened and followed the instructor, we were curious if any other interactions happened directly among the students, potentially simulating the type of socializing that occurs on the edges of a real tour. Interestingly, Student 1 remarked: “we make eye contact, … you know someone is looking at you … when you see the avatar … so you wave hands.” Several students also remembered the clapping function (fig. 9), or watching other students use the drawing tools to create lines and arrows in the air during the tours. This influenced further students to experiment with the software tools in the app. Overall, however, we were disappointed by the lack of functionality that would enable students to directly interact. As Student 3 said, “I don’t think we’ve had that much interactions with each other,” as she remembered “just staring at their avatars, … but we don’t have like physical interactions like through our avatars’ bodies.” One potential direction for better interaction was noted by Student 6 who said: “this [other] person drew sort of like a cup and I was able to hold it.” This type of object-based interaction could be useful for studying archaeology. We would also like to see the capability for easy private voice communications between two individuals.

The students mentioned that they faced some technological challenges with using the headset and software, as well as a tendency to get lost or struggle to control motion through the space. Students 1 and 2 could not figure out how to get down to the terrain model when we entered a space floating in the air, so they switched over to the web browser interface. Student 3 noted that it was possible to get stuck in the geometry because you could “accidentally go into the interior space of the building and you don’t know how to get out of it.” For the tour of the Armenian site, she also said that because “there’s like ridges and mountains and it’s easy to get lost because sometimes you don’t know … where … the group is.” Student 4 observed that “in virtual reality, we kind of [get] lost … cause there’s so much information to process, … in the virtual reality we have to use our brain to imagine … [that] we are standing on the place.” She suggested that the software implement a small top-view map so users could locate themselves in the environment, similar to some video games. She appreciated the north arrow floating in the sky as a way to navigate, though Student 1 found that difficult to use while moving.

We also asked the students about how they would improve the VR experiences. Student 2 recommended that we put more effort into the surface textures, to make it look more varied and realistic. Student 3 wanted to do the tours “together in a room … because in that sense you are really having a sense of being in that group, instead of conducting this on our own.” Student 7 suggested meeting face-to-face to learn about and troubleshoot VR, noting that as “we are instructed via Zoom … the people who would like to help us could not … identify the problem easily.” We hope that some combination of improvements in the ease-of-use of the hardware and software, together with our efforts to increase student digital literacy will make future VR experiments smoother.

Discussion

We undertook only a pilot experiment, with the goal of learning about what works, and what does not, for implementing VR in the classroom as embodied experiential learning. Although there were some technical challenges with using the equipment, many of the students reflected on the use of VR as a very positive and interesting learning experience. Student 6 noted that “using the VR to see these spaces and actually look at them is a very new perspective[, different] from just reading from the sources.” Student 3 made the important observation that in VR “we basically have a sense … of the relative distance between us and the physical surrounding.” The student reactions point to the potential for this technology to motivate learners, perhaps a result of VR’s novelty and “fun-factor” (Kavanagh et al. 2017).

We began this article by laying out the pedagogical context for visual and spatial learning about archaeology sites. We were pleased that students remembered well the spatial layouts of the VR-introduced sites, even after a few months, so that they could describe them. However, we also recognize the potential for combining this VR-based spatial learning with traditional teaching methods that help students remember the sociocultural aspects of sites. By bringing together multiple pedagogical tools, we hope to instill an even more comprehensive understanding of the past. We believe that the students’ spatial learning was enhanced by the embodied experiential learning they undertook through virtually moving around the sites on their own (Kiefer and Trumpp 2012; Kolb 2014). This allowed them to simulate the types of knowledge construction one would have at a real site when their bodies, eyes, and mind are synchronized. They were learning in a variety of ways that differ from traditional classroom experiences. We see this as approaching a more authentic learning experience. We also learned that the VR system could enable some social interactions that support learning, though this aspect of the technology could be further developed. Being a part of a virtual group, while asking questions and engaging in discussion, seemed to make learning more interesting and impactful. We also found that it was quite feasible to deploy VR as part of a remote learning strategy, which has the potential to make distant archaeological sites accessible to new groups of students (Looi, Wye, and Abdul Bahri 2022).

We now have a clearer sense of the logistical requirements of building models and organizing the tours. Creating high quality models is challenging, but our basic models did support spatial teaching. Building models from archival sources could be a learning experience itself (Garstki 2022). Then, if archaeologists would publish reusable 3D models, either from their fieldwork or from archival reconstruction, further experiments with VR would be much easier for everyone. Overall, we found our pilot experiment to be useful, both to demonstrate the potential for spatial learning and to help us understand how to improve the use of VR in the classroom. Our future focus will be on designing educational experiments specifically to measure and enhance student spatial and visual learning through these immersive, authentic experiences. We also hope to explore using games and competitions to motivate learning and to use the technology itself to record and measure student experiences.

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