Abstract

This paper presents a case study evaluating how 3D modeling and virtual reality (VR) support learning in an online archaeology course through an immersive tomb reconstruction assignment. Implemented as the Honors component of an asynchronous general education course, the project asked students to rebuild ancient Egyptian tombs in SketchUp and present them in a shared virtual environment. Across two iterations (Spring and Fall 2025), students engaged with mortuary architecture, spatial reasoning, and—when required—embedded ethics-focused elements addressing issues such as looting, repatriation, colonial legacies, and the display of human remains.

Survey data and thematic reflections (n = 44) show that although most students began with little modeling experience and high concern, they reported reduced anxiety, modest gains in digital confidence, and higher perceived learning than with traditional assignments, particularly in spatial understanding and interpretive engagement. Qualitative responses emphasized creativity and ownership alongside recurring technical friction. Ethical outcomes showed high baseline concern and modest refinement rather than major shifts, with no consistent differences between students who embedded ethics in their models and those who engaged through readings alone.

Overall, findings indicate that immersive reconstruction can enhance engagement and spatial learning in online archaeology courses when supported by careful scaffolding and attention to cognitive load.

Introduction

Immersive technologies such as virtual reality (VR) and 3D modeling are reshaping how archaeology and related disciplines approach teaching, particularly in online learning environments. Archaeology's reliance on visual, spatial, and material forms of evidence makes it especially well suited to immersive and three-dimensional pedagogies (Cobb et al. 2024). Within education more broadly, immersive environments have been framed as a response to widespread student disengagement, offering experiential, affective, and participatory modes of learning aligned with what Hu-Au and Lee (2017) describe as the emerging "Experience Age." At the same time, recent experimental research cautions that immersion alone does not guarantee learning gains; highly immersive environments may heighten emotional arousal while undermining learning transfer if instructional scaffolding is insufficient (Parong and Mayer 2021). Together, these perspectives suggest that immersive technologies hold significant pedagogical promise, but only when carefully designed and evaluated.

To examine these questions in practice, we implemented and evaluated a digital archaeology project in the course Classics 150C1: Pyramids and Mummies:

The Pharaoh in Ancient Egyptian Society, an asynchronous online general education course taught through the University of Arizona. The project involved reconstructing ancient Egyptian tombs using SketchUp for 3D modeling and FrameVR for hosting and exploring a shared virtual environment. By using these innovative and interactive technologies, the project aimed to bring history to life while also challenging students with technical and ethical questions. In this paper, we present our project framework, share student feedback on both the immersive and technical aspects, and outline our next steps to refine and improve this educational approach.

Literature Review

The primary goal of this study is to better understand the role that 3D modeling and VR can play in teaching archaeology. Recent studies have demonstrated that immersive VR and 3D environments offer transformative potential for archaeology education by enhancing both cognitive and affective learning outcomes. For example, Stephan (forthcoming) highlights the challenges of maintaining student engagement in online, asynchronous settings, arguing that immersive digital projects can counteract the disengagement often seen in remote classrooms by offering hands-on, experiential learning opportunities. Cobb and colleagues (2024) argue that because archaeology relies so heavily on visual, spatial, and material forms of evidence, pedagogical approaches that employ digital 3D, virtual, mixed, and augmented reality (AR) technologies are particularly well aligned with the disciplinary nature of archaeological learning.

Building on the promise of immersive learning, Slater (2017) identifies five key advantages of employing VR in education: transforming the abstract into the concrete; promoting active “doing” rather than passive observing; making the infeasible or impossible practical; enabling learners to manipulate digital environments; and extending learning beyond the constraints of physical reality. These advantages provide a framework for understanding how VR can reshape the educational experience in archaeology, offering learners unique opportunities to engage with historical content in vivid, interactive ways. Hu-Au and Lee (2017) go even further. Situating VR within the broader shift toward an “Experience Age,” they suggest that immersive learning environments respond directly to contemporary challenges of student disengagement while supporting the development of skills such as empathy, creativity, and complex reasoning.

Empirical support for VR’s impact comes from Lund and Wang (2019), whose work demonstrates that first-person VR experiences enhance motivation and spatial understanding, even if immediate test score improvements are modest. Similarly, Garstki, Larkee, and LaDisa (2019) show that immersive 3D environments facilitate deeper spatial and visual comprehension of archaeological sites, allowing students to virtually explore excavation trenches and artifacts in ways that are unfeasible in

traditional classrooms. In a field-based educational context, Derudas and Berggren (2021) demonstrate that incorporating 3D technologies into archaeological training encourages students to engage in sustained three-dimensional reasoning across excavation, recording, and interpretive stages of archaeological practice.

More recent work by Stephan, Doery, and Simmons (2025) confirms that while VR may not fully replicate the experience of visiting an archaeological site in person, its interactive representations significantly enrich the learning process by bridging the gap between abstract historical narratives and tangible reality. Liritzis, Volonakis, and Vosinakis (2021) further contribute by demonstrating that 3D reconstructions, such as their virtual tours of Delphi, can make historical content more accessible, and engaging through interactive narration and multimedia elements. Bekele et al.'s (2018) survey of augmented, virtual, and mixed reality systems in cultural heritage highlights how these technologies support user-centered engagement and broaden access to heritage content, particularly within educational and interpretive settings.

Falconer and colleagues (2020) extend these findings by illustrating that high levels of sensory immersion evoke a powerful sense of presence, leading to emotional and even physical reactions that enhance the overall learning experience. Smith (2019) argues that VR represents a natural evolution in educational technology, shifting students from passive information receivers to active, self-directed learners capable of controlling and personalizing their educational journey. From the perspective of public archaeology, Ellenberger (2017) emphasizes that VR and AR can be especially effective pedagogical tools because they capture attention and encourage affective connections to the past through embodied interaction with archaeological spaces and materials.

A secondary goal of this study is to assess student perspectives on group work within asynchronous online courses. To frame this investigation, a substantial body of research examines the pedagogical implications of individual versus group work in online undergraduate education. Collaborative projects are frequently associated with benefits such as communication skill development, exposure to diverse perspectives, and increased motivation (Ashikullah et al. 2024). However, studies also document persistent challenges, particularly in asynchronous environments, including coordination difficulties, uneven participation, interpersonal conflict, and concerns about "free riding" (Donelan and Kear 2023). Individual work, by contrast, is often valued for flexibility, focus, and personal accountability, though it may increase feelings of isolation and limit opportunities for peer learning (Ashikullah et al. 2024). Importantly, students commonly report that the effectiveness of individual or group work depends on the nature of the task and learning context, suggesting that no single instructional format is universally optimal.

Another secondary focus of our investigation was on the role that VR might play in teaching students about archaeological ethics. Although archaeological ethics is a

well-developed field of scholarly debate, relatively little research examines how these ethical frameworks are actually taught in undergraduate or introductory archaeology settings. Much of the ethics literature—on topics such as stewardship, repatriation, colonial legacies, and the treatment of human remains—is written for professional archaeologists and assumes substantial disciplinary background, making it less accessible as a pedagogical tool for novice learners. Moe and colleagues (2002) note that even when ethical decision-making is acknowledged as central to archaeological practice, explicit instruction in ethical reasoning is rarely integrated into classroom design, resulting in students encountering ethics only incidentally through course content rather than as a structured learning outcome. Arias-Ferrer and Egea-Vivancos (2017) similarly argue that archaeological training tends to emphasize technical competence while leaving moral and interpretive responsibilities underexamined, advocating for pedagogies that foreground ethics as a core competency rather than an implicit expectation. Together, these studies highlight a significant gap in archaeology education: while ethics is foundational to the discipline's professional identity, pedagogical models for teaching ethical awareness remain limited, ad hoc, and largely undeveloped. This gap underscores the need for instructional designs—such as immersive or interpretive assignments—that scaffold ethical reflection in intentional and accessible ways.

Despite its potential, the use of VR and 3D modeling in education presents a range of shortcomings that must also be considered. From a technical perspective, the high cost of hardware and software remains a significant barrier, particularly for underfunded institutions, limiting the scalability and equitable adoption of immersive technologies (Allison 2008; Liritzis, Volonakis, and Vosinakis 2021; Liu et al. 2017). Even when resources are available, instructors and students often face a steep learning curve, compounded by time-consuming troubleshooting, software compatibility issues, and the challenge of integrating VR into existing pedagogical frameworks (Dede, Jacobson, and Richards 2017; Stephan, forthcoming). Infrastructure demands, such as the need for high-speed internet and advanced computing power, can further complicate implementation (Richards 2017).

Educators also face difficulties in assessing student progress and contributions within virtual spaces, raising questions about the effectiveness of VR in evaluating learning outcomes (Liu et al. 2017). Perhaps most concerning is the risk that the novelty of VR technology overshadows its pedagogical purpose. As Fowler (2015) argues, VR should not merely deliver flashy digital experiences but must be carefully designed to enhance explanation, foster deeper understanding through interaction, and support learning within its broader social context. Without this alignment, VR risks becoming more about technological spectacle than meaningful educational transformation (Allison 2008; Nobles, Çakirlar, and Svetachov 2019). Parong and Mayer (2021) reinforce this concern through experimental findings showing that highly immersive VR experiences

may heighten emotional arousal while simultaneously hindering learning transfer when cognitive scaffolding is insufficient.

Taken together, the literature provides a robust foundation for evaluating the role of VR and 3D modeling in archaeology education. Slater's (2017) five-part framework is broadly supported across these studies. For instance, Garstki, Larkee, and LaDisa (2019); Lund and Wang (2019); and Stephan, Doery, and Simmons (2025) all emphasize VR's ability to make abstract archaeological content more concrete and immersive. Liritzis, Volonakis, and Vosinakis (2021) and Falconer et alia (2020) underscore how VR extends learning beyond the physical classroom and fosters emotional engagement, echoing Slater's focus on presence and interactivity. Theoretical work on embodied cognition from Kiefer and Trumpp (2012) further supports these approaches, emphasizing that learning is grounded in sensory, perceptual, and motor experience, providing a cognitive framework for understanding why interactive and immersive pedagogies can be effective. Smith (2019) also frames VR as a means of transforming students from passive recipients to active learners, another of Slater's key points. At the same time, scholars such as Fowler (2015) and Liu and colleagues (2017) offer important caveats, noting that technical and pedagogical limitations can diminish these benefits if not carefully addressed. This synthesis affirms Slater's framework as a valuable interpretive lens while reinforcing the broader scholarly consensus that VR, when thoughtfully integrated, holds significant promise for enhancing archaeology education.

On balance, however, these studies underscore the multifaceted benefits and occasional challenges of integrating 3D modeling and immersive environments into archaeology education. They collectively provide a robust foundation for exploring how these technologies can enhance engagement, spatial understanding, and ethical reasoning, setting the stage for our investigation into the practical impacts of VR and 3D modeling projects in the classroom.

The Project

This project was implemented as the Honors component of Classics 150C1: Pyramids and Mummies: The Pharaoh in Ancient Egyptian Society, an asynchronous online general education course at the University of Arizona. The course ran in two iterations, Spring 2025 and Fall 2025, each enrolling approximately 1,000 students overall. Within each offering, a small cohort of Honors students completed an enriched project that operated alongside the core course curriculum. Because the Honors component was embedded within a large-enrollment, fully online course, it was designed to function almost entirely asynchronously, with only limited synchronous engagement.

The course followed a compressed 7.5-week schedule equivalent to a traditional 15-week semester. Within this structure, the Honors project was largely self-directed.

Students were provided with written instructions, curated research materials, and a sequence of instructional videos, but there was no regular live meeting schedule. Apart from an optional Q&A session and a final project showcase, all modeling, research, and preparation occurred asynchronously.

The central task of the Honors project was the digital reconstruction of an ancient Egyptian tomb from either the Valley of the Kings or the Valley of the Queens. Students selected a tomb and worked primarily from materials provided by the Theban Mapping Project, including published floor plans, measurements, photographs, and descriptive documentation, supplemented where appropriate by excavation reports and additional visual sources. Using these materials, students translated two-dimensional archaeological evidence into a navigable three-dimensional model. The pedagogical goal was neither technical mastery of 3D modeling nor exhaustive historical accuracy, but rather an immersive, hands-on approach to understanding mortuary architecture, burial practices, and the interpretive challenges inherent in reconstructing the ancient past.

Students used SketchUp as the primary modeling platform and FrameVR as the virtual environment in which to present the completed tombs. SketchUp was selected for its accessibility, relatively low barrier to entry, and extensive ecosystem of publicly available tutorials. To supplement these resources, the instructional team produced eight custom video tutorials guiding students through foundational modeling skills, architectural construction, and the application of materials and textures. Once completed, models were imported into FrameVR, a browser-based, multi-user virtual environment that allowed students to explore one another's tombs as avatars. FrameVR's cross-platform compatibility, no-code interface, and support for synchronous exploration made it suitable for hosting the final project showcase. Students were encouraged, but not required, to use VR headsets, and information about borrowing devices from the university library system was provided to reduce access barriers.

Throughout the project, emphasis was placed on architectural fidelity and interpretive decision-making rather than aesthetic polish. Students worked to scale using published measurements and floor plans and making choices about movement, visibility, and spatial relationships within the tomb. In this respect, the assignment functioned as a form of digital archaeological synthesis, requiring students to assemble disparate sources into a coherent spatial interpretation. The process was intentionally framed as exploratory and iterative, prioritizing engagement with evidence over the production of a flawless model.

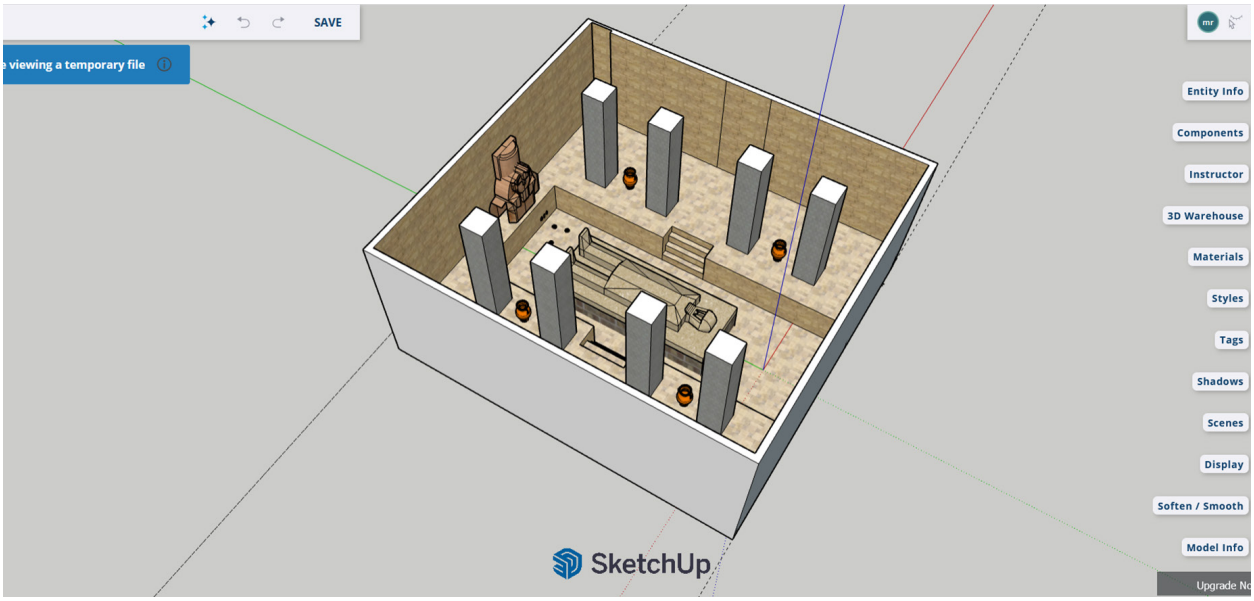

Figure 1. A student's 3D model of the tomb of Ramesses III, as it appears in SketchUp.

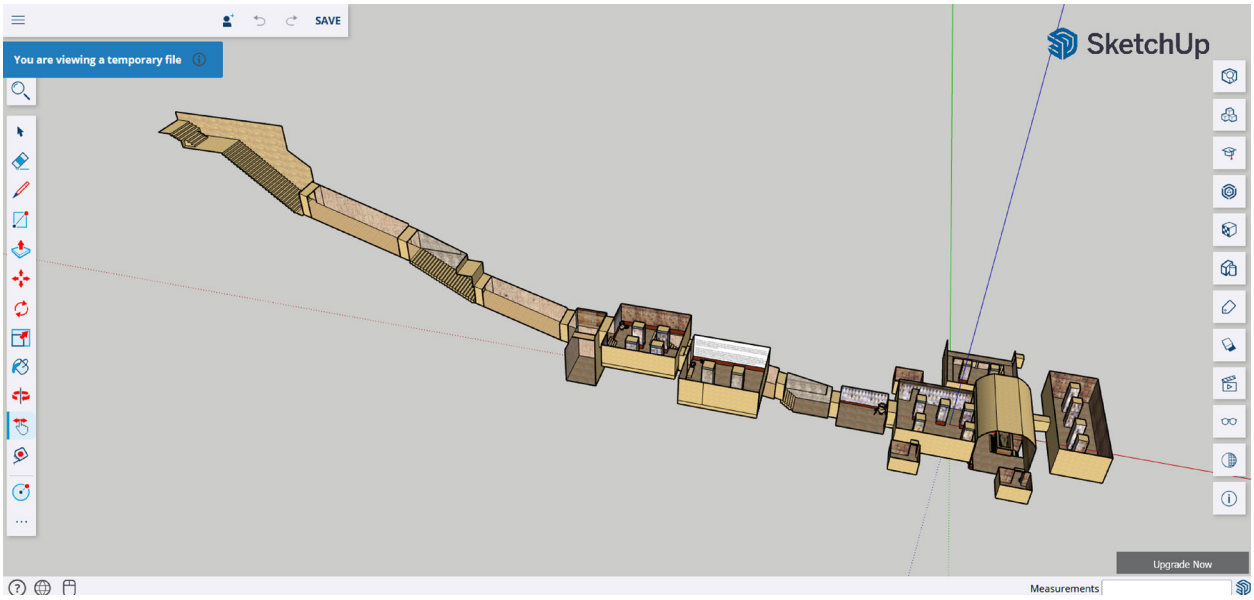

Figure 2. A student's 3D model of the tomb of Horemheb, as it appears in SketchUp.

A final component of the project required students to engage with archaeological ethics. All students completed readings addressing contemporary ethical debates surrounding the display of human remains, cultural heritage ownership, colonial legacies in Egyptology, and the responsibilities of museums and archaeologists. In some iterations of the project, students were also asked to embed an ethics-focused element directly within their digital tomb, such as textual placards or interpretive notes, prompting reflection on the ethical implications of reconstructing and presenting funerary contexts in digital form.

Figure 3. A screenshot from the virtual presentation in FrameVR of Hatshepsut's unused tomb, located in the Valley of the Kings. Virtual participants look at an information panel the student created to communicate the ethical considerations incorporated into the model.

The project culminated in a virtual showcase hosted in FrameVR for the Honors student participants. For each iteration of the course, a dedicated two-hour session was scheduled in which students shared their completed reconstructions. In the smaller Spring 2025 cohort, students guided peers and instructors synchronously through their reconstructed tombs as avatars within the virtual space, discussing architectural features, historical context, modeling challenges, and, where applicable, the ethical considerations that shaped their design choices. As the Honors cohort expanded in Fall 2025, synchronous participation became optional, and many students instead submitted recorded video walkthroughs of their models. Together, these presentation formats functioned as a summative assessment and a reflective capstone experience, situating individual projects within a broader collective exploration of ancient Egyptian mortuary culture and its modern interpretation.

Figure 4. A screenshot from the virtual presentation of the sons of Ramesses II tomb in FrameVR.

Methodology

This study utilized pre- and post-course surveys to assess student experiences with 3D modeling and immersive virtual environments within an online archaeology course.

These pre- and post-project surveys were designed to capture both quantitative and qualitative dimensions of student experience. Surveys were distributed electronically at the beginning of the course and again after the completion of the 3D modeling project and virtual presentation. The pre-project survey collected data on students' prior experience with 3D modeling, self-rated technological proficiency, anticipated concern, and emotional orientation toward the assignment. The post-project survey assessed perceived learning gains, project difficulty, changes in technical confidence, satisfaction with the assignment, and reflections on the effectiveness of VR and 3D modeling as instructional tools.

Beginning in Fall 2025, additional survey items were introduced to investigate two further dimensions of the project. First, students were asked about their perceptions of group work in asynchronous online courses, including prior experience, comfort level, and overall evaluation of collaborative work in this context. Second, the Fall 2025 cohort was divided into two groups to explore whether the mode of engagement with archaeological ethics influenced student perceptions. Approximately half of the students

were required to actively integrate an ethics-focused component into their digital tomb in addition to completing the assigned readings, while the remaining students engaged with ethical material solely through readings and reflective discussion. This structure enabled a comparison between passive engagement with ethics through readings and active, design-based operationalization of ethical concerns.

Quantitative survey data were analyzed descriptively, focusing on means, distributions, and changes in self-reported measures. Given the exploratory nature of the study, small sample sizes, and pedagogical context, inferential statistical testing was not emphasized. Qualitative responses were analyzed thematically to identify recurring patterns related to engagement, learning, technical challenges, collaboration, and ethical reflection. Direct student quotations are presented in the Results section to illustrate these themes and ground the analysis in student voice.

Taken together, this methodology was designed to capture both measurable shifts in student perceptions and the nuanced experiential dimensions of learning through immersive digital reconstruction. While student self-report data provide only indirect evidence of learning outcomes, they offer a valuable lens for evaluating the pedagogical affordances and limitations of 3D modeling and virtual environments in online archaeology education.

Results

The findings presented below combine student responses from two iterations of the assignment: an initial pilot in Spring 2025, which yielded 9 survey responses from a cohort of 15 Honors students, and a second implementation in Fall 2025, which produced 35 responses from 157 Honors students. Although the Fall survey included several additional questions not asked in the Spring, the assignment itself ran in an identical format across both semesters. Aggregating the two datasets therefore provides a moderately robust basis for evaluating trends in student learning, technological development, attitudes toward group work, and engagement with archaeological ethics.

Student Background and Initial Expectations

Across both semesters, students entered the assignment with extremely limited background in 3D modeling. Of the 32 respondents who responded to the pre-project survey, 13 had no experience at all, 11 had very little, and only 8 reported anything more than minimal familiarity; no student described their background as extensive. Thus, 75% of the students were essentially novices upon beginning the project. Despite this lack of specialized preparation, students' general technological confidence was moderate (M = 5.7/10), indicating that while they felt reasonably comfortable with digital tools overall, they did not yet possess the skills required for architectural or spatial reconstruction.

Emotional expectations reflected this gap between general digital fluency and modeling-specific uncertainty. Students reported a relatively high level of concern going into the assignment (M = 6/10, n = 25), suggesting that the project felt intimidating before they began. The attitudinal spectra collected in the Fall cohort reinforce this picture: students leaned slightly more nervous than calm (2.3/5, with 3 being "neutral"), afraid rather than joyful (2.8/5), and frustrated rather than thriving (2.7/5). Yet even amid this apprehension, their intellectual orientation was notably positive—they rated themselves far more curious than bored (3.9/5) and moderately enthusiastic rather than apathetic (3.2/5).

On the whole, then, these data portray a cohort beginning the project with low modeling experience, moderate technological confidence, and a complex emotional profile: high concern paired with genuine curiosity. This combination created a productive starting point for learning, positioning the 3D tomb reconstruction assignment as both a challenge and an opportunity for students to expand their technical and interpretive capacities.

Students selected their own tombs to model, resulting in a surprisingly wide distribution of monuments from both the Valley of the Kings and the Valley of the Queens. Although the assignment allowed complete freedom of choice, the final dataset includes reconstructions of major royal tombs (e.g., those of Tutankhamun, Ramesses III, Sety I, Sety II, and Queen Tyti), as well as several less frequently discussed monuments.

In addition to the architectural modeling, all students in Spring 2025 and half of those in Fall 2025 were required to integrate a component addressing archaeological ethics into their virtual tomb. These elements took different forms across the cohort but tended to be textual interventions embedded within the 3D space. Common approaches included placards explaining the ethics of displaying human remains, notes on the history and impact of looting, statements on the removal or dispersal of grave goods, and reflections on cultural ownership and repatriation. While these components varied in scope and creativity, they collectively demonstrate students' ability to connect technical reconstruction with ethical interpretation. See the "Project" section and Fig. 3 for an example of these ethical integrations.

Quantitative Results

Post-project survey data indicate measurable shifts in students' confidence and affective responses following completion of the 3D modeling assignment. Self-reported technological proficiency increased from M = 5.7 before the project (n = 32) to M = 6.1 afterward (n = 39), suggesting modest but meaningful gains in digital confidence across cohorts. More striking was the reduction in anxiety: students' reported concern about the project—and about undertaking a similar assignment in the future—declined

from *M* = 6.0/10 (*n* = 25) to *M* = 4.6/10 *(n* = 36). This shift indicates that while students initially perceived the project as intimidating, engagement with the modeling process substantially reduced apprehension, even if technical mastery remained limited.

Self-perceptions of learning were also broadly positive. On a 5-point scale comparing the assignment to a traditional essay project, students reported an average perceived learning score of 3.6/5. Most respondents indicated learning gains: 30 students indicated they felt they learned somewhat or significantly more using VR and 3D modeling, compared to 7 who felt they learned about the same and 7 who reported learning less. Perceived difficulty clustered near the midpoint (*M* = 3.4/5, *n* = 44), indicating that the project was challenging but not overwhelming for most students. These results suggest that immersive 3D reconstruction proved challenging—somewhat more so than a traditional research paper—but also intellectually fruitful, with self-perceptions of confidence and learning increasing for a majority of students.

Qualitative Results

Qualitative responses reveal strong engagement with the creative and experiential dimensions of the assignment, alongside substantial frustration with software and technical logistics. Many students emphasized the novelty and intrinsic appeal of the project, describing it as “very fun and educational,” a “super fun, creative project,” and a “unique way to present this type of information.” Several explicitly contrasted it with traditional coursework, noting that they “enjoyed getting to create a 3D model rather than writing an essay,” that it was “way more fun than just writing an essay or something,” and that it offered “a unique learning experience” compared to other courses. Students frequently highlighted visualization as pedagogically meaningful: “having to redesign the tomb in a 3D modeling software helped me better understand the burial rituals,” and “the project was a fun way to bring the tomb to life and gave me a better look into how amazing it truly is.” Others emphasized creative ownership and satisfaction, commenting that “I loved having the creative flexibility to put our own spin on the tomb,” and that “being able to see the project as a third person POV inside the tomb was also super cool.”

Instructional scaffolding emerged as a key factor in positive experiences. Many students praised tutorials and support resources, noting that “the instructional videos were extremely helpful,” “the tutorials worked really well,” and “watching Youtube videos helped soooo much because I was pretty lost at first.” Institutional support spaces were also critical for some students: “I thought going to the Catalyst studio worked well for me. If I didn’t do that, I don’t know how I would’ve managed this project.” Even students who struggled often described a sense of accomplishment once progress was made, writing that “once I got used to the controls in Sketchup, the project as a whole was very easy,” or that “as frustrating as the overall learning curve was it was pretty rewarding to see what it looked like when I was finished.”

At the same time, technical barriers were a dominant theme. Many students described SketchUp and FrameVR as difficult or unstable, particularly for those without prior modeling experience. Students reported that “the 3D modeling software feels badly designed for those inexperienced with it,” that “SketchUp was not very user friendly at first,” and that “it was incredibly difficult to figure out software and technology as someone who has never done it before.” File conversion and VR integration were frequent points of failure: “the conversion from SketchUp to FrameVR was pretty difficult,” “the FrameVR software was a pain in the butt to use,” and “the VR was extremely glitchy and I had trouble moving and configuring camera angles.” Several students detailed lost work, glitches, or overheating hardware, reporting that “it deleted my work after saying that it was saved,” or that “my computer overheated and it crashed the SketchUp software.”

These technical challenges shaped perceptions of learning for some students. A minority expressed concern that effort shifted away from disciplinary content: “I unfortunately don’t think that I was focused on learning about the tomb and more about constructing it with the software,” and “learned more about 3D modeling than about ancient Egypt.” Others explicitly preferred alternative formats, stating, “I would’ve just rather written a paper,” or suggesting that “having one-to-three options for this project in varying formats . . . would’ve been really nice.” Nevertheless, even among critical responses, students often acknowledged the project’s conceptual value, describing it as “interesting but difficult,” “daunting but cool,” or “challenging but in a good way.”

On the whole, students frequently framed the assignment as demanding yet meaningful: “it seemed like a lot at first, but I ended up really enjoying the project”; “the project was still tough, but not extremely hard to the point where I just wanted to be done with it”; and “I think it was a challenging and unique project.” Many expressed pride in their work and in their final products, despite imperfections. Thus, the qualitative data suggest that immersive 3D reconstruction fostered engagement, creativity, and deep visualization for many students, while also introducing technical friction that, for some, constrained enjoyment and shifted focus away from archaeological content.

Several students described the immersive and spatial qualities of the project as central to their learning experience, particularly in relation to understanding tomb architecture, burial practices, and funerary symbolism. Students emphasized that seeing their models take shape helped transform abstract course content into concrete, memorable experiences. One student commented that they “liked seeing the tomb come to life” and felt that this process helped them learn “the intricate details of the tomb.” Others noted that the act of modeling supported retention and synthesis, with one student stating they could “probably redesign Queen Tyti’s tomb from memory,” due to the combination of background research and hands-on construction.

In addition to spatial learning, several students reflected on the emotional and ethical dimensions of working within a shared virtual environment. The final showcase, where students explored one another's tombs, was frequently cited as a highlight that encouraged reflection beyond technical skill-building. One student remarked that the project was "way more fun than just writing an essay," while others emphasized the value of encountering lesser-known burial sites and considering how ancient lives were represented digitally. These reflections suggest that immersion and shared virtual presence contributed not only to engagement but also to broader considerations about representation, responsibility, and interpretation within archaeological practice.

Ethical reflection also emerged in student responses, particularly as students considered the physical realities of archaeological practice. One student questioned not only the ethics of display but also the ethics of excavation labor itself, asking: "Is [it] ethical to have anyone crawling around in these dangerous spaces? . . . And is it ethical to send people in there in the first place? Especially for Hatshepsut's tomb, which was built into a cliff face. That was all something I hadn't considered before." This response illustrates how engaging with tomb architecture through 3D reconstruction prompted students to reflect on ethical issues related to safety, labor, and responsibility—dimensions of archaeological practice that are often abstract or invisible in traditional coursework.

Student Perceptions of Online Group Work

The Fall 2025 survey also investigated student perceptions of group work in asynchronous online classes. In this cohort, 19 post-project survey respondents completed the project individually and 15 worked in groups. Prior to the course, students reported very limited experience with asynchronous group work (M = 1.7/5) and low preference for group projects in online settings (M = 2.3/5, with 3.0 being "neutral"). These attitudes remained largely unchanged by the end of the course, with student preference very slightly increasing (M = 2.4/5) and student "comfortability" with group work slightly decreasing (3.1 → 3.0). This suggests that participation in the project neither substantially improved nor substantially worsened baseline views of asynchronous collaboration. When asked to evaluate group work more holistically on a 1–10 scale, responses were widely distributed (M = 5.4, n = 33), again indicating mixed overall impressions rather than consensus.

Qualitative responses help explain this ambivalence. Students who worked successfully in groups emphasized efficiency, accountability, and shared creativity, noting that "the group I picked turned out great, everyone did their part easily," that "working in a group forced me to stay on top of my assigned tasks," and that it was "fun working with another person and sharing our ideas." Several students believed group work improved outcomes, suggesting that "my tomb would've had significantly more detail," or that collaboration allowed them to "combine our knowledge to make a more

accurate tomb." Challenges were common, however, particularly around communication and software constraints. Students reported that "people won't communicate," that they were "rejected or ghosted," and that collaboration was difficult because, in SketchUp, "only one person can actually complete the tasks at a time." Some preferred individual work, expressing concern that group projects added stress or diluted ownership: "I would have been more overwhelmed working in a group," or "I still felt proud of it knowing that I did all of the work for it." Taken together, the findings suggest that asynchronous group work was highly contingent on preexisting relationships, communication reliability, and technological limitations, functioning well for some students while reinforcing skepticism for others.

Digital Approaches to Archaeological Ethics

Across the combined Spring 2025 and Fall 2025 cohorts, students entered the course with relatively high baseline awareness of archaeological ethics, leaving limited room for dramatic shifts but allowing for modest changes in emphasis. Mean scores increased across all five ethical categories from pre- to post-survey. The largest absolute gains were observed in "Looting and Illicit Trade" (7.42 → 7.91; +0.49, +7%) and "Commercialization and Exploitation" (6.90 → 7.39; +0.49, +7%), suggesting heightened sensitivity to the economic dimensions of archaeological harm. Smaller increases were observed for "Colonialism and Cultural Appropriation" (+0.30, +4%), "Respect for the Dead and Cultural Sensitivity" (+0.17, +2%), and "Loss of Context and Integrity" (+0.10, +1%). Taken together, these results indicate incremental strengthening of ethical concern rather than wholesale shifts in student values.

Scenario-based questions reveal more nuanced changes in ethical reasoning. When asked whether human remains should be displayed in museums, student responses moved away from singular conditional positions toward greater dispersion. In one formulation of the question, support for display only under conditions of both scientific value and descendant permission declined (69% of student answers → 18% of student answers), while responses emphasizing either descendant permission alone (13% → 23%) or scientific value alone (16% → 23%) increased. A small number of students adopted more absolute positions after the course, either opposing display entirely (3% → 7%) or endorsing unrestricted display (0% → 7%). A parallel question showed a similar pattern: post-course responses included increases in both conditional ethical frameworks and permissive views, indicating that engagement with course materials prompted reflection rather than convergence on a single ethical stance.

Responses concerning the repatriation of artifacts likewise suggest clarification rather than polarization. Support for returning artifacts regardless of circumstances remained almost the same (13% → 14%), while endorsement of legality-based conditional retention became very slightly more common (38% → 42%). Case-by-case reasoning also remained neutral (31% → 30%), reinforcing the tendency toward contextualized

ethical judgment. Together, these findings suggest that the course did not push students toward a uniform ethical position but instead encouraged more differentiated, articulated reasoning about archaeological ethics.

To explore whether actively operationalizing archaeological ethics within a creative digital project produced different outcomes than engaging with ethics through readings alone, the Fall 2025 cohort was divided into two groups. One group (n = 15) was required to integrate an explicit ethics-focused component into their 3D tomb model (e.g., interpretive placards addressing looting, the display of human remains, or the modern location of displaced artifacts, etc.), while the comparison group (n = 20) completed the same weekly ethics readings without a required design-based intervention. Mean post-project scores across the five ethical categories show no clear or consistent pattern distinguishing the two groups. Students who integrated an ethics component scored slightly higher on “Respect for the Dead and Cultural Sensitivity” (+0.18, +2%) and “Commercialization and Exploitation” (+0.07, +1%), and notably higher on “Looting and Illicit Trade” (+0.92, +12%). However, this group scored modestly lower on “Colonialism and Cultural Appropriation” (-0.17, -2%) and “Loss of Context and Integrity” (-0.28, -4%). Rather than indicating a uniform benefit or detriment associated with active incorporation, the mixed directionality of these changes suggests that embedding ethics into creative work did not reliably intensify ethical concern across domains. Given the small sample sizes and the relatively high baseline ethical awareness observed across the cohort, these findings should be interpreted cautiously. Overall, the data suggest that while students can meaningfully engage with ethical issues through both reading-based and design-based approaches, active integration alone does not appear to produce a systematically stronger ethical orientation.

Discussion

The findings of this study demonstrate that immersive 3D modeling can function as a productive—but demanding—pedagogical strategy in online archaeology education. Across the two iterations of the assignment, students entered the project with minimal prior experience in 3D modeling, moderate general technological confidence, and relatively high levels of concern. Yet, despite this apprehension, most students reported meaningful learning gains, reduced anxiety, and strong engagement with both spatial and interpretive dimensions of archaeological content. Taken together, these results suggest that immersive reconstruction projects are capable of supporting learning even among novice users, provided that sufficient instructional scaffolding and flexibility are in place.

Interpreted through Slater’s (2017) framework, several of the core advantages of immersive learning were evident. The act of reconstructing tomb architecture appears to have helped students transform abstract information about such as burial practices, spatial organization, and funerary symbolism into concrete, memorable structures. This

aligns with prior work emphasizing the importance of three-dimensional reasoning in archaeological education (Derudas and Berggren 2021; Garstki, Larkee, and LaDisa 2019). Importantly, students' reported gains were not limited to technical skills; many described enhanced understanding of archaeological context and spatial relationships, suggesting that the modeling process supported integrative learning rather than isolated skill acquisition.

At the same time, the results complicate more optimistic narratives surrounding immersive technologies. While many students found the project engaging and rewarding, technical friction was pervasive. Software instability, file conversion issues, and hardware limitations shaped students' experiences and, for some, diverted attention away from archaeological interpretation toward troubleshooting. These findings reinforce longstanding cautions that immersive technologies do not automatically produce improved learning outcomes and may hinder transfer if cognitive load is not carefully managed (Fowler 2015; Liu et al. 2017; Parong and Mayer 2021). In this sense, the project's success was not a function of immersion alone, but of how immersion was mediated through instructional design, tutorials, and support structures.

One of the most significant contributions of this study lies in its examination of ethical reasoning within an immersive learning context. Students entered the course with relatively high baseline awareness of archaeological ethics, leaving limited room for dramatic shifts. Rather than converging toward a single ethical position, post-course responses became more differentiated and context-sensitive. Students increasingly articulated conditional reasoning around issues such as display, repatriation, and scientific value, suggesting refinement rather than transformation of ethical perspectives. This pattern supports Angelelli and colleagues' (2023) argument that interactive environments foster ethical engagement by prompting students to confront complexity, ambiguity, and responsibility, rather than by transmitting prescriptive moral conclusions.

Notably, embedding ethics directly into the 3D modeling process did not yield uniformly stronger ethical outcomes compared to reading-based engagement alone. While some ethical categories showed modest gains for students who integrated ethics into their models, others declined slightly, and no consistent pattern emerged across domains. This finding suggests that active incorporation does not automatically intensify ethical concern; instead, it may redistribute attention across different dimensions of ethical reasoning. Given the already high baseline awareness observed, immersive design-based approaches may function more effectively as spaces for ethical exploration and questioning than as mechanisms for measurable attitudinal change.

The mixed outcomes associated with asynchronous group work further highlight the contingent nature of immersive pedagogy. Students' attitudes toward collaboration were shaped less by the assignment itself than by social dynamics, communication

reliability, and software constraints. While some groups experienced increased accountability and creativity, others encountered frustration, disengagement, or logistical barriers. These findings align with broader research on online collaboration, which emphasizes that group work effectiveness depends heavily on task structure and technological affordances rather than participation alone (Ashikullah et al. 2024; Donelan and Kear 2023).

Taken together, the results suggest that immersive 3D modeling projects are best understood not as universally superior alternatives to traditional assignments, but as pedagogical tools that introduce distinctive trade-offs. They appear particularly well suited to fostering spatial understanding, creative ownership, and reflective engagement with archaeological practice, including its ethical dimensions. However, they also demand careful calibration to avoid overwhelming students or displacing disciplinary learning with technical frustration. When thoughtfully designed, immersive projects can expand what is pedagogically possible in online archaeology education—not by simplifying learning, but by making its complexities visible, navigable, and open to critical reflection.

Advice and Future Directions

Advice for Educators

Based on our experience, we offer a few suggestions for others considering a similar project. First, while it might be tempting to allow students to choose from a wide range of tomb options, it is important to be mindful of the technical complexity involved in each. Some students selected elaborate, multilevel tombs with ramps and staircases, which added considerable modeling challenges without significantly enhancing the final immersive experience. As one student remarked, “The amount of work and effort required was really up to the individual.” We recommend curating a set of preapproved tombs or chambers that offer an equitable balance of historical interest and modeling difficulty to help ensure a more consistent workload across the class.

Second, we recommend curating a focused set of video tutorials, or even creating custom ones that are tailored specifically to the goals of the project. Students noted that the tutorials we linked to and created ourselves were helpful components of the experience. By narrowing the resources to content directly related to tomb construction, we reduced the time students spent searching through unrelated videos, such as those focused on modern interior design. This not only made the modeling process more efficient but also allowed students to concentrate on applying the software to archaeological reconstruction, rather than trying to adapt general SketchUp content to a completely different context.

Third, instructors using platforms like FrameVR to host the virtual environment should be aware of limitations related to collision detection in imported SketchUp models. FrameVR does not automatically generate collision meshes from SketchUp files, which can lead to technical issues. For example, users might spawn outside the model or unintentionally flying through walls and floors, disrupting the immersion. To mitigate this, we suggest building in time before the final presentation to process the models in Blender or a similar tool. Creating custom collision meshes ahead of time can significantly improve the stability and realism of the shared virtual experience.

Future Directions

Building on the promising results of this pilot project, several future directions offer potential to deepen its pedagogical impact and better understand the mechanisms behind student learning and ethical development.

First, we aim to conduct a comparative study of perceived learning and ethical shifts between students who complete immersive VR/3D projects and those who engage in more traditional final assignments, such as research papers or slide presentations. While our initial data suggest students felt they learned more and developed a stronger ethical awareness through the VR project, these impressions merit closer comparison with parallel cohorts using conventional methods. By administering the same pre- and post-course surveys to both groups, we hope to isolate the specific contributions of immersive, hands-on design to ethical reflection and content retention.

Second, future iterations of the project will seek to disaggregate the effects of 3D modeling and VR to better understand their individual and combined impacts. Currently, students engage with both tools simultaneously, but it remains unclear whether the perceived learning gains and ethical insights stem more from the act of digitally reconstructing the tomb, the immersive VR experience of exploring it, or the synergy of both. To investigate this, we plan to design variations of the assignment in which some students only model tombs without using VR, while others explore pre-built tombs in VR without building them. These experiments will help clarify the roles of embodiment, creation, and immersion in shaping student outcomes.

Third, we envision expanding the project into a persistent, cumulative 3D world, a shared virtual reconstruction of a major archaeological site such as the Valley of the Kings, Giza, or fifth-century BCE Athens. In this model, each semester's students would add new structures, features, or interpretive elements, gradually populating a richly detailed, student-built historical landscape. Such a framework could support longitudinal learning, as students build on the work of their peers, critique past reconstructions, or develop site-wide narratives across tombs, temples, and public spaces. It would also open opportunities for interdisciplinary collaboration, with students from different

courses or departments contributing architectural reconstructions, interpretive signage, video tours, or ethical commentary. In this way, the classroom would become a kind of evolving research lab, and students would emerge not just as learners, but as co-creators of a digital heritage environment with lasting educational value.

Fourth, future research would benefit from incorporating more in-depth qualitative methods, such as semi-structured interviews, to further examine how students experience immersive 3D modeling and virtual environments in archaeology education. While the present study relied on surveys and written reflections, interviews could allow researchers to probe students' reasoning processes in greater detail, particularly regarding spatial understanding, affective engagement, and ethical interpretation. Such methods would be especially valuable for unpacking how students articulate the relationship between technical challenges, creative decision-making, and disciplinary learning, as well as how immersive environments shape ethical reflection over time. Conducting interviews alongside or shortly after project completion would also help clarify how students integrate these experiences into their broader understanding of archaeology and digital heritage. Incorporating qualitative interviews in future iterations—supported by appropriate IRB approval—would therefore provide a richer evidentiary base and help refine best practices for designing immersive, ethics-centered archaeology assignments at scale.

Finally, although this project was implemented as an Honors component within a large-enrollment asynchronous course, its underlying pedagogical mechanisms are not inherently limited to an Honors population. Core elements of the assignment—spatial reasoning through reconstruction, learning-by-making, iterative problem-solving, and ethical reflection prompted by representational choices—are broadly applicable to undergraduate archaeology education. However, scaling this project to a full-class implementation would require targeted structural adjustments. These include more tightly curated modeling options to ensure equitable workload, expanded scaffolding through staged milestones and guided checkpoints, and flexible assignment pathways that allow students to engage through individual or collaborative formats depending on their preferences and technical comfort. Additionally, maintaining VR as an optional enhancement rather than a requirement would help mitigate access barriers while preserving the benefits of immersive exploration. Future work will explore how these modifications affect learning outcomes in larger and more heterogeneous student populations, with particular attention to balancing engagement, accessibility, and cognitive load in asynchronous environments.

Conclusion

This project explored how immersive technologies, specifically 3D modeling and VR, can enhance learning in archaeology education. Our findings suggest that for the Honors students in this course, creating and exploring digital tomb reconstructions

helped transform abstract historical concepts into concrete experiences. Students reported that the hands-on modeling process and the immersive virtual presentation deepened their understanding of tomb architecture, burial rituals, and ethical considerations around cultural heritage. Many described the project as more engaging and educational than traditional assignments, with some indicating it was the most memorable experience of their Honors coursework to date.

However, it is important to note several caveats. This was a small-scale case study involving only Honors students, who are generally more self-motivated than the broader undergraduate population. Their high level of autonomy, willingness to troubleshoot technical challenges, and motivation to excel likely shaped the positive outcomes reported here. Additionally, the culminating synchronous presentation, where students explored each other's tombs together, is not a typical feature of asynchronous online courses and may have played a key role in fostering peer engagement. Our data also rely on student self-reports rather than direct assessments of learning artifacts, meaning that perceived gains do not necessarily equate to measurable knowledge or skill increases. Furthermore, the significant technical hurdles some students faced with SketchUp suggest this approach may not be universally accessible without intensive support.

Despite these limitations, this initiative supports existing theories that immersive, interactive approaches can foster spatial awareness, ethical reflection, and deeper engagement with cultural heritage. While our findings are based on a single, small cohort and should be interpreted with caution, they align with prior research demonstrating the potential of VR and 3D modeling to move students from passive learning toward active, experiential understanding. Future studies involving larger and more diverse student populations, as well as direct evaluation of learning artifacts, will be necessary to confirm and extend these results. Even so, this project highlights how thoughtfully designed immersive activities can open new pathways for students to engage with archaeological content, grapple with ethical complexities, and build digital skills relevant beyond the classroom.

Ethics committee approval

This study was reviewed and approved by the University of Arizona Institutional Review Board (IRB) under ID number STUDY00005441.

Participant consent

Participation in all surveys was voluntary, responses were anonymized, and all procedures complied with institutional guidelines for research involving human subjects.

Supplemental Materials

https://www.notion.so/LINKS-Digital-Heritage-and-Ethical-Display-Student-Reflections-on-Recreating-Funerary-Contexts-in-305ff43f355c80558e89f856d18995ca?source=copy_link

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