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When Archaeology Comes to Life in 3D: From Virtual Reality to Archaeogaming

ABSTRACT: This article offers an overview of how digital technologies are increasingly applied in archaeology and heritage communication. Selected examples are highlighted that illustrate how these methods support documentation, reconstruction, and public presentation of archaeological heritage. In addition, the emerging field of archaeogaming is discussed as a way in which archaeological content finds new entry points into popular culture and education. Rather than providing a comprehensive study, the article aims to demonstrate how digital approaches can enrich both archaeological practice and heritage communication, while also raising questions about authenticity, sustainability, and social responsibility.

Keywords: Digital Archaeology; Cultural Heritage; Heritage Communication; Public Archaeology; Archaeogaming

1 Introduction

Archaeology has undergone a profound methodological transformation in recent decades. While 3D scanning and 3D modelling have become standard tools of archaeological documentation, digital visualisations, augmented reality (AR), and virtual reality (VR) are opening new pathways for communicating archaeological research (e.g. Bekele 2017; Ellenberger 2017; Vincent et al. 2017; Evans and Daly 2006; Barceló, Forte and Sanders 2000). These technologies are increasingly applied not only in scientific projects and museums, but also in cultural tourism, public education, and the broader field of public archaeology (Merriman 2004; Curk 2022), which is also gaining importance in Slovenia (see also Jana Puhar in this volume).

Archaeology has always been an interdisciplinary discipline, combining methods from the humanities and natural sciences to trace the cultural development of humanity from its beginnings to historical times. It

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seeks to reconstruct social and economic forms of organization, as well as symbolic and spiritual expressions, through artefacts and immovable remains. In this sense, archaeology makes a fundamental contribution to understanding the foundations of modern civilizations.

Cultural heritage, at the centre of this discipline, is a sensitive and non-renewable component of collective memory. Its preservation and communication require not only traditional archaeological methods, but increasingly also innovative digital approaches. The aim of this article is to demonstrate, through selected examples, how new technologies can help to 'bring archaeology to life' and make cultural heritage accessible to a wider audience, while also supporting new interpretative approaches that seek to understand the people behind the material remains – both in the past and in the present.

2 Archaeological Heritage as a Societal Resource

Archaeological heritage constitutes a fundamental foundation for understanding the cultural development of past and present civilizations. UNESCO has emphasized culture as a global public good, underscoring that cultural heritage is a sensitive and irreplaceable resource worthy of protection[2]. Yet, this heritage is increasingly endangered by a variety of natural and anthropogenic factors, including geological processes, climate change, urban expansion, industrial development, and agriculture[3]. Examples such as large-scale mining of lignite in Germany (Stäuble 2010) or the creation of artificial reservoirs demonstrate the irreversible destruction of archaeological sites. Even where heritage authorities attempt to document, comprehensive recording often proves impossible, as for example in the Upper Euphrates region of southeastern Turkey, where sites such as Nevalı Çori sank beneath the waters of the Atatürk Dam reservoir (Schmidt 2016, 68).

Armed conflicts add a further dimension to the threat. Targeted destruction of sites, looting of museums, illegal excavations and trafficking

2 UNESCO 20241212_Policy Brief Culture as a Global Public Good: https://www.unesco.org/sites/default/files/medias/fichiers/2024/12/20241212_Policy%20Brief%20Culture%20as%20a%20Global%20Public%20Good.pdf.
3 UNESCO World Heritage in Danger: https://whc.unesco.org/en/danger/.

of artefacts have become widespread phenomena, as illustrated by the devastation of Nimrud in Iraq and Palmyra in Syria (e.g. Perko 2018; Turku 2018; Khunti 2018, 1) or the destruction of the Buddha statues in the Bamyan Valley in Afghanistan (Petzet 2009). More recent cases, such as damage to heritage sites and museums in Gaza and Ukraine, show that cultural heritage remains acutely vulnerable in contemporary conflicts. Illegal excavations also continue to devastate archaeological landscapes; for instance, at the site of Isin in Iraq, uncontrolled digging has left the terrain riddled with craters, permanently erasing contextual information essential for archaeological interpretation (e.g. van Ess, Hilgert and Salje 2014, 375, fig. 65.4).

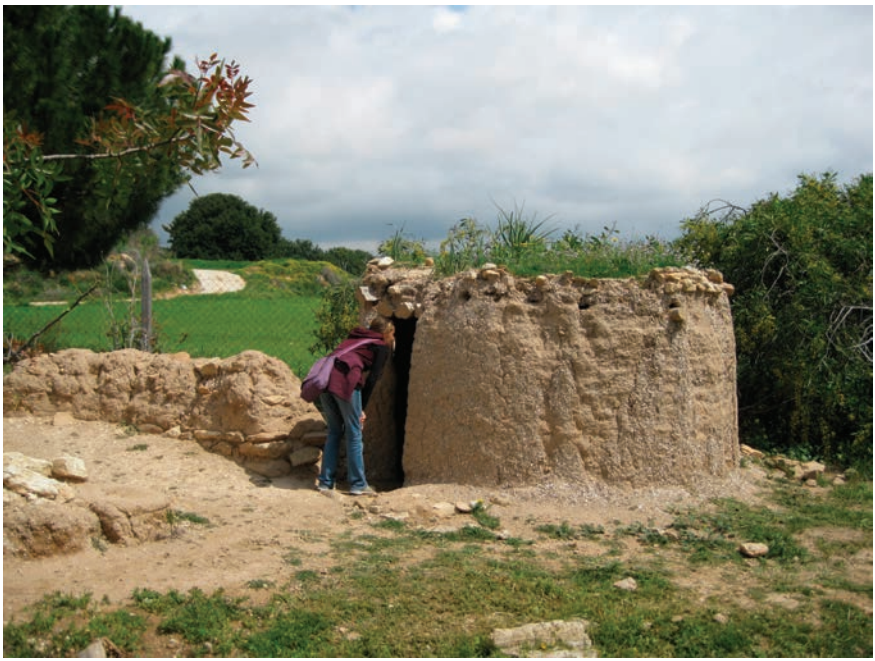
Against this background, the role of archaeology extends well beyond the reconstruction of ancient cultures. International frameworks, such as the Council of Europe's *Strategy 21,* highlight heritage as a bridge for intercultural understanding and societal connection (Pirkovič 2019)[4]. Adopted in 2017, the strategy outlines three key dimensions: the social component (heritage as a factor of well-being), the economic and territorial component (heritage as a driver of development and cultural tourism), and the knowledge component (heritage as a field of education and research). Archaeological and cultural heritage is thus framed not only as a scientific concern, but also as a resource with broad social and economic significance.

This perspective resonates with the concept of collective memory, first introduced by Maurice Halbwachs in *Les cadres sociaux de la mémoire* (1925) (Halbwachs 1980) and later further elaborated by Aleida and Jan Assmann, who emphasized its role in shaping cultural identity. Archaeological heritage forms part of a shared memory, shaped by space, time, rituals and objects, thereby connecting communities across generations. It can foster intercultural dialogue, promote inclusion, create employment opportunities, and enhance quality of life. In this sense, heritage emerges as both a research subject and a societal responsibility – reflecting the explicit goals of *public archaeology* and the central mission of contemporary museums (Merriman 2004).

4 Https://www.coe.int/en/web/culture-and-heritage/strategy-21.

Building on these insights, the challenge lies in how to communicate and render heritage accessible in the 21st century, in line with the principles of the Council of Europe's *Faro Convention on the Value of Cultural Heritage for Society* (2005)[5]. Traditional approaches – reconstruction drawings, scale models, reconstructions (Figure 1) and information panels at sites – are now increasingly complemented by advanced digital methods, including 3D visualization, augmented reality (AR), and virtual reality (VR). These techniques not only enrich museum displays and archaeological parks, but also expand access beyond academic contexts. In alignment with *Strategy 21*, innovative technologies are explicitly recommended as a means of making cultural heritage more widely available and strengthening its role as a global common good (compare Pirkovič 2019, 19–21).

Figure 1: Reconstruction of chalcolithic buildings at the Lemba archaeological site on Cyprus. Photo credit: Bine Kramberger.



5 Https://www.coe.int/en/web/culture-and-heritage/faro-convention.

3 Digital Methods in Archaeology

Archaeological knowledge has traditionally been derived from excavation, which is an inherently invasive process in which stratigraphic layers are uncovered, documented, and ultimately destroyed (e.g. Fera 2019; Pedeli and Pulga 2013; Barker 1993)[6]. Accurate recording through drawings, photographs, and measurements has therefore always been essential to preserve contextual information. While excavations remain indispensable, especially in the context of rescue archaeology, the last two decades have witnessed an increasing reliance on non-invasive techniques that safeguard the archaeological record while still generating rich data (e.g. Mušič et al. 2019; Bertók and Gáti 2014; Czajlik and Bödőcs 2013; Neubauer et al. 2013)[7].

Airborne laser scanning, or LiDAR, has become a particularly transformative method (e.g. Doneus and Fera 2019; Opitz and Cowley 2013). Laser scanners mounted on aircraft or drones capture millions of elevation points to create detailed digital models of the surface. These models allow archaeologists to detect features hidden beneath forest canopies or otherwise invisible from the ground. In many regions – from the South American rainforest (e.g. Prümers 2023, 31–37) to European cultural landscapes (e.g. Czajlik et al. 2019; Czajlik and Bödőcs 2013) – LiDAR has enabled the identification of entire archaeological landscapes without disturbing a single layer of soil, thereby reducing both costs and destruction.

Terrestrial laser scanning represents a complementary technique (e.g. Fehér 2013). By generating dense point clouds, it enables the creation of highly accurate three-dimensional models of sites, structures, and monuments. The method enables the recording of archaeological features with remarkable precision, allowing the reconstruction of spatial units that would otherwise be lost after excavation (e.g. Ludwig 2023; Zimmermann

6 The literature on the various analog and digital methods used in archaeological research in the past, and which are now standard practice in archaeological fieldwork, is extensive. The publications cited here can therefore only serve as examples.

7 See also Urankar's documentation system Zoot, developed for cultural heritage recording and museum integration (Urankar, Krajšek and Lipovec 2024).

and Capriuoli 2023). Similarly, Structure-from-Motion photogrammetry, which is based on the stitching of overlapping photographs, has emerged as a cost-effective tool for producing 3D models (e.g. Ludwig 2023, 53). Together, these techniques provide unprecedented accuracy compared to earlier analogue reconstructions.

Such technologies also enable sophisticated reconstructions of cultural heritage. A striking case is the Roman temple quarter in Baalbek, Lebanon, where 3D laser scanning has facilitated both meticulous documentation and a virtual reconstruction of the monumental complex (Burwitz 2023)[8]. The resulting application, Baalbek Reborn: Temples, integrates archaeological research with tourism, education, and cultural exchange. Baalbek, a UNESCO World Heritage Site and a long-standing venue for cultural festivals, illustrates the meaningful interweaving of science, heritage protection, and public engagement.

Beyond architecture, 3D scanning has revolutionized the documentation of artefacts (e.g. Schepers 2023; Ritter et al. 2023). Whereas objects were once recorded through technical drawings and photography, digital models now allow for detailed analysis and versatile modes of presentation. In some museum contexts, visitors can engage with interactive 3D displays or holograms[9], offering immersive encounters with archaeological objects and enhancing accessibility.

The integration of three-dimensional data further supports augmented reality (AR) applications that overlay reconstructions onto real-world environments via smartphones or tablets (e.g. Rivero et al. 2024; Ellenberger 2017; Vlahakis et al. 2002). Such applications enable visitors at archaeological sites to visualize monuments in their original form using smartphones, thereby deepening their experience. Virtual reality (VR) extends these possibilities by immersing users directly in reconstructed environ-

8 Researches in Baalbek, Lebanon, by the German Archaeological Institute (DAI): https://www.dainst.org/forschung/projekte/noslug/4484?tx_wfdaiprojects_projects%5Bnav%5D=open&cHash=3b7aa586f8a97e09771f4a166e878247.

9 For example in the LWL-Museum for Archaeology and Culture in Herne, Germany: https://www.lwl-landesmuseum-herne.de/de/unsere-digitalen-angebote/ .

ments (Barceló, Forte and Sanders 2000)[10]. Unlike AR, VR requires specialised equipment, yet it allows for highly interactive exploration, whether at archaeological sites, in museums, or in educational settings.

Finally, digital methods also extend beyond reconstructions of the past and include the creation of virtual museums (e.g. Carvajal, Morita and Bilmes 2020; Perko and Nestorović 2017; Styliani et al. 2009; Moscati 2007), where immersive and interactive online exhibitions are developed that simulate the museum experience in a digital space. Accelerated by the COVID-19 pandemic, these platforms offer a level of accessibility previously impossible: exhibitions can be viewed from anywhere and at any time, bypassing geographical, temporal or mobility-related constraints. They may include features such as 3D walkthroughs of galleries, high-resolution object models, annotated context information, multimedia content, and user interaction to deepen understanding. Such initiatives strongly resonate with the Council of Europe's *Strategy 21*, which places accessibility as a core principle in heritage management, advocating that cultural heritage must be comprehensible, participatory, and accessible to all. Beyond offering access to exhibitions, such platforms also open up new possibilities for interactive learning and participation, paving the way for innovative applications that combine education and digital engagement.

Together, these digital techniques transform the practice of archaeology by enhancing documentation, enabling reconstruction, and expanding public access. They are also of key importance for precise museum documentation, musealisation processes, and virtual reconstructions (Rodriguez-Garcia et al. 2024). They lay the groundwork for novel forms of engagement, including archaeogaming, which integrates archaeological content into digital entertainment and will be examined in the following section.

10 One example is the VR-Station of the Archaeological Museum Münster, Germany, which allows visitors since 2024 to experience early Christian heritage in today's Turkey (Asia Minor): https://www.uni-muenster.de/ArchaeologischesMuseum/aktuelles/doliche_vr.html. Another example is the 'virtual tour' into the Hallstatt salt mine in the Natural History Museum Vienna, Austria: https://www.nhm.at/en/research/prehistory/virtual_reality.

4 Archaeogaming: Science and Popular Culture

The emergence of 'archaeogaming' illustrates how archaeological knowledge and digital media intersect in novel ways (Mol et al. 2017; Reinhard 2018). The term itself has several meanings. As Andrew Reinhard has argued in his *Archaeogaming: An Introduction to Archaeology in and of Video Games* (2018), the term can refer to both the representation of archaeology in video games and to the archaeological study of games themselves as cultural artefacts. A striking example of the latter is the so-called 'Atari video game burial' in New Mexico, where unsold consoles and cartridges have become objects of contemporary archaeology (Reinhard 2018, 23–29). For the purposes of this article, however, the emphasis lies on the former: the integration of archaeological content into digital environments.

The aforementioned technologies, such as 3D scanning and visualization, provide the basis for the creation of historically grounded virtual worlds (Rodriguez-Garcia et al. 2024)[11]. These can serve as settings for games inspired by ancient civilizations such as Ancient Rome, for digital reconstructions used in narrative sequences, or even for interactive simulations of excavation techniques. Such applications allow players not only to explore the reconstructed past, but in some cases also to assume the role of archaeologists themselves – reminiscent of popular figures such as Indiana Jones[12] or Lara Croft (Deuber-Mankowsky 2005).

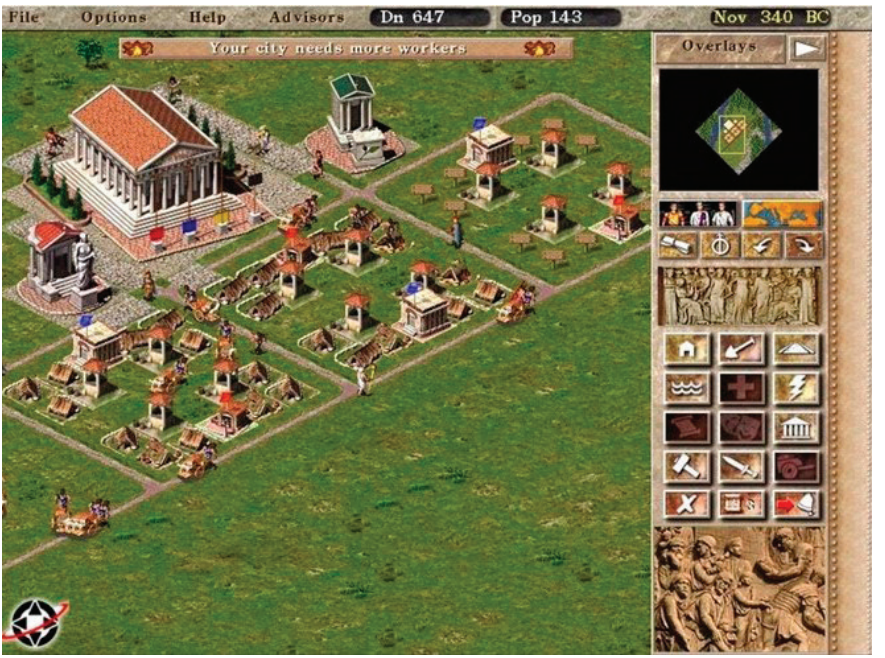
The spectrum of archaeogaming ranges from entertainment to education. One pioneering experiment was the digital reconstruction of the Neolithic site of Çatalhöyük in Turkey within the platform *Second Life* between 2007 and 2012 (Morgan 2009; 2019, 327–329). Based on excavation data, this virtual environment enabled students and their instructors to explore the prehistoric settlement with their avatars. This can be understood as a form of experimental archaeology in digital space, blending scholarly research with experiential learning.

11 See also: https://www.wessexarch.co.uk/archaeological-services/virtual-reality-vr-augmented-reality-ar-and-gaming.

12 The title character Dr. Henry Walton 'Indiana' Jones of the 'Indiana Jones' franchise was created by American filmmaker George Lucas: https://www.lucasfilm.com/productions/raiders-of-the-lost-ark/.

Commercial games also contribute to archaeogaming in diverse ways. Classic strategy titles such as *Caesar III*[13] (Figure 2) or *Age of Empires*[14] embed archaeological and historical knowledge into their mechanics, guiding players through the expansion of empires and the construction of ancient cities. At the same time, such examples also highlight the need for critical evaluation: to what extent do these games convey historically grounded knowledge, and where do they risk simplifying or distorting the past (compare Reinhard 2018, 192)? A systematic assessment of their impact remains essential, not only to identify their potential for public education, but also to address the ethical implications of how archaeology and history are represented in popular media.

Figure 2: Construction of an 'ancient Roman city' in the Video Game Caesar III (by Impressions Games). Screen capture by author.

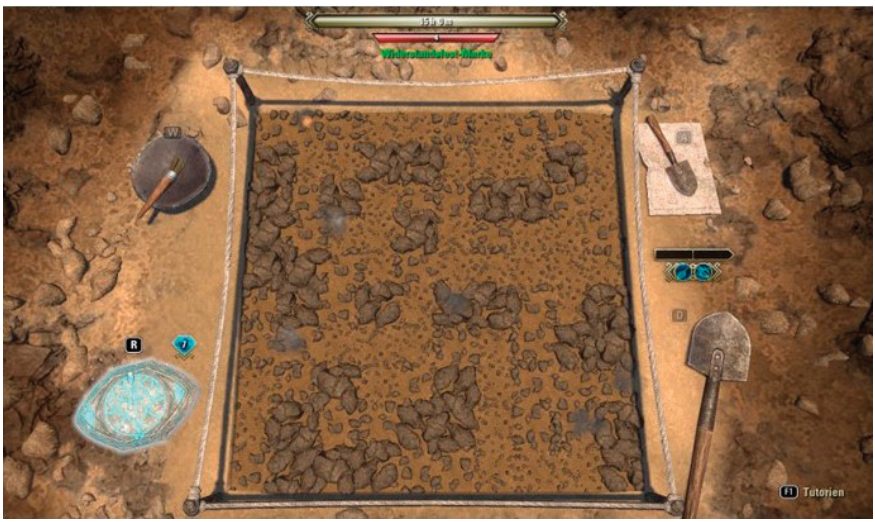


13 Developed by Impressions Games and released in 1998: https://archive.org/details/Caesar_III_Sierra_Studios_Impressions_1998.

14 The first part of the franchise was developed by Ensemble Studios and released in 1997.

Other games depict archaeological practice, albeit with varying degrees of accuracy. An interesting example is *The Elder Scrolls Online* (ESO) (compare Reinhard 2018, 82–86), where excavation is presented as a specialized activity. Players must complete training at the 'Antiquarian Circle' before they are allowed to excavate; they then use a range of tools to uncover artefacts layer by layer (Figure 3). Errors in using the tools risk damaging the finds, which are subsequently assessed by experts and can even be displayed in museums. Although archaeology is not the central theme of the game, but rather a side activity, its mechanics echo real-life archaeological procedures and highlight, to a certain degree, the need for professional training.

Figure 3: 'Archaeological excavation' in the Video Game Elder Scrolls Online (by Zenimax Online Studios). Screen capture by author.



However, the popular image of archaeology is often shaped more by stereotypes than by reality. The enduring influence of Indiana Jones[15] has fostered an adventurous, treasure-hunting cliché that diverges sharply from the scientific practice of archaeology. This is reinforced by media portrayals that conflate archaeology with the aforementioned clichés, or by television programs that glamorize the use of metal detectors to search for

15 See footnote 10.

'treasures' by hobby 'archaeologists'[16]. In Europe, such activities are heavily regulated, and unsupervised searching represents a serious challenge for heritage protection (e.g. Jurišić et al. 2019, 59, 61, 67, 75). The marketing of real and toy metal detectors[17], which fail to clearly communicate legal restrictions, illustrates the persistent gap between popular perception and archaeological practice (Gaspari 2018, 2022).

These examples underline the dual potential of archaeogaming and the (popular) communication of archaeological science: it can both reinforce misconceptions and provide opportunities for more accurate and engaging representations of archaeology. The challenge lies in harnessing digital platforms not merely for entertainment, but also to raise awareness of archaeology as a scientific discipline and to communicate its methods and responsibilities to a wider public. These reflections also resonate with broader initiatives in digital heritage, such as virtual museums and online exhibitions, where the boundaries between entertainment, education, and public communication are increasingly fluid. In this context, 'serious games' are particularly promising, as they are explicitly designed to combine entertainment with educational objectives, and have been shown to foster learning and engagement in cultural heritage contexts (Mortara et al. 2014).

4.1 Case Study: Iron-Age-Danube and Digital Tools

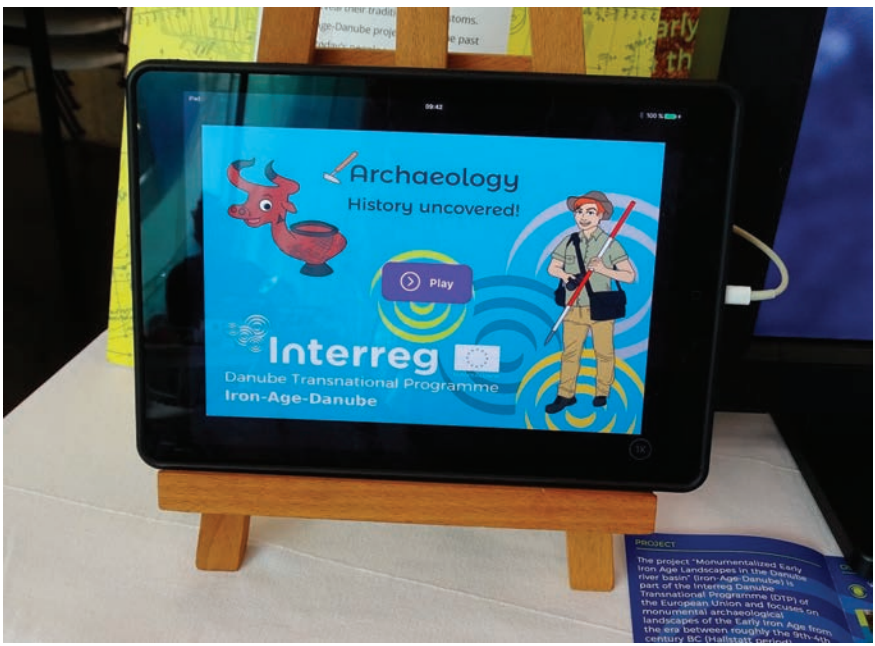
An illustrative example of how archaeology can integrate digital media into both research and public communication is the Interreg *Iron-Age-Danube project*. The project 'Monumentalized Early Iron Age Landscapes in the Danube river basin' (Iron-Age-Danube), led by Marko Mele and the Universalmuseum Joanneum (Graz), ran from 2017–2019 and was part of the Interreg Danube Transnational Programme of the

16 For example in the American reality television series 'Diggers' (2013–2015) on National Geographic. The show has been discontinued, but it is still being re-broadcast on television. The Society for American Archaeology took action against the show since it was encouraging the looting of archaeological sites: https://www.huffpost.com/entry/archaeologist_n_1315867.

17 For example the model CANGSTARTDET6L by Bluemarble, sold under the product description National Geographic Metal Detector Starter Kit for Kids.

European Union[18]. Within this framework, the consortium developed the e-learning application 'Archaeology: History Uncovered', which combined serious content with game elements and was available in five languages (Mele 2021, 70; Hellmuth Kramberger 2021, 71) (Figure 4). The app guided users through the entire archaeological workflow – from preliminary research and project approval to excavation, documentation, and post-excavation analysis – thereby countering common stereotypes and misconceptions about archaeology.

Figure 4: Start screen of the app 'Archaeology: History Uncovered', developed by the Iron-Age-Danube (2017–2019) project. Photo credit: author.



The application offered two modes: a 'Learn' mode with interactive explanatory elements and a 'Play' mode in which users advanced through levels by correctly solving tasks. The integration of 3D visualizations as 'rewards' provided an additional immersive dimension and demonstrated the potential of digital technologies for science communication.

18 Https://dtp.interreg-danube.eu/approved-projects/iron-age-danube.

The app exemplifies how digital tools can translate archaeological practice into accessible formatsand bridge the gap between professional research and a wider audience. It also shows how heritage communication can benefit from interactive and playful approaches that not only increase outreach but also foster a deeper understanding of archaeology as a scientific discipline.

6 Conclusion and Outlook

The examples discussed in this article demonstrate how digital technologies are reshaping both the practice and communication of archaeology. Techniques such as 3D scanning, photogrammetry, and laser scanning have moved beyond purely technical applications to become essential tools for reconstructing past environments, safeguarding endangered sites, and enabling innovative forms of public engagement (Little 2002). Augmented and virtual reality further expand these possibilities by offering immersive experiences that connect heritage with contemporary audiences in ways that traditional media have not been able to achieve.

Archaeogaming and educational applications demonstrate that archaeology can find new entry points into popular culture and public discourse. When designed responsibly, such approaches do not trivialize the discipline but instead open creative avenues for explaining its methods, correcting misconceptions, and fostering interest across generations. The *Iron-Age-Danube* project, with its integration of digital learning tools and interactive elements, illustrated how playful approaches can still convey serious content and stimulate deeper awareness of archaeology as a scientific practice. Linking these approaches with the developments in virtual museums and online platforms suggests that archaeogaming is not an isolated phenomenon, but part of a wider trend in which digital technologies foster novel forms of participation and learning across different audiences.

At the same time, the growing reliance on digital mediation raises important challenges. Questions of authenticity, accuracy, and ethical responsibility must remain at the centre of archaeological research and heritage communication. Virtual reconstructions and game environments, while powerful, risk simplifying or distorting complex realities if not critically designed and contextualized. Moreover, long-term sustainability – both

technical and financial – must be addressed to ensure that digital outputs remain accessible beyond the short lifespan of individual projects.

Beyond these general challenges, several ethical questions deserve particular attention (compare e.g. Boruvková 2025; Khunti 2018; Richardson 2018). How much interpretation is acceptable in digital reconstructions, and where is the line between plausibility and speculation? Transparency is equally critical: audiences must be able to distinguish between what is securely documented, what is reconstructed, and what is hypothetically added. Cultural sensitivity is also essential, as reconstructions may unintentionally reproduce narratives that fail to do justice to certain communities or perspectives. Finally, the issue of long-term digital authenticity arises, since models often circulate in public perception as 'real', even though rapid technological change can quickly render them outdated. Addressing these concerns requires not only technical expertise, but also critical reflection, ethical guidelines, and clear communication with diverse audiences.

Looking forward, the field of digital heritage research will increasingly depend on interdisciplinary collaboration, involving not only archaeologists but also computer scientists, designers, educators, and policymakers. If pursued with care, digital archaeology can strengthen the role of cultural heritage as a bridge across societies, as envisaged by international frameworks such as *Strategy 21*. It has the potential to contribute to social well-being, intercultural dialogue, and lifelong learning, while simultaneously enriching archaeological scholarship itself (Moscati 2007; Merrimen 2004; Little 2002).

In this sense, bringing archaeology 'to life' in the 21st century is not only a matter of technological innovation, but also of social responsibility (Dallas 2007). Digital tools must be understood as a means of engaging the wider public, protecting endangered resources, and reaffirming the relevance of archaeology in contemporary society[19].

19 This article was supported by the Slovenian Research and Innovation Agency (ARIS) within the research group 'Raziskave kulturnih formacij / Research of Cultural Formations (P6-0278 (A), 2019–2027)' at Alma Mater Europaea University.

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