American Antiquity (2025), 1–25
doi:10.1017/aaq.2024.82

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Society for American Archaeology

ARTICLE

Ethical Considerations in the Use of 3D Technologies to Preserve and Perpetuate Indigenous Heritage

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(Received 27 February 2024; revised 27 September 2024; accepted 15 October 2024)

Abstract

The past decade saw the proliferation of projects that use 3D and related technologies to engage with Indigenous heritage through museum collections and cultural heritage site digitization projects involving the documentation and sometimes physical replication of objects and landscapes; some of these projects involved Indigenous origin communities. Although 3D technologies have become more widespread and accessible, ethical considerations in practice lag behind. The "Ethical Considerations in Three-Dimensional Digitization of Indigenous Heritage" project unites researchers, members of Indigenous communities, and 3D heritage specialists to develop a set of best practices for the responsible conduct of research (RCR). These practices promote ethical cultures in science, technology, engineering, and math (STEM) fields, recognizing Indigenous heritage 3D modeling as a critical part of the broader conversation around decolonization and core methodologies. This article proposes incorporating best practices developed from the RCR findings for 3D digitization projects of Indigenous cultural heritage. We suggest utilizing **C**ollective benefit, **A**uthority to control, **R**esponsibility, and **E**thics (CARE) principles, Indigenous Data Sovereignty, and a co-production of knowledge (CPK) framework.

Resumen

En la última década, se ha visto una proliferación de los proyectos que utilizan tanto tecnologías de representación tridimensional como tecnologías vinculadas a la interacción con el patrimonio indígena, a través de proyectos de digitalización 3D de colecciones de museos y sitios del patrimonio cultural que implican la documentación y, en ocasiones, la reproducción física de objetos y paisajes, y con algunos ejemplos en los que participan comunidades de origen indígena y descendientes de indígenas. Si bien las tecnologías 3D se han vuelto más comunes y accesibles, las consideraciones éticas en la práctica aún están rezagadas. El proyecto «Ethical Considerations in Three-Dimensional Digitization of Indigenous Heritage» (Consideraciones Éticas en la Digitalización Tridimensional del Patrimonio Indígena), reúne a investigadores, miembros de comunidades indígenas y especialistas en patrimonio 3D para desarrollar un conjunto de mejores prácticas para la Conducta Responsable de la Investigación (en inglés *RCR—responsible conduct of research*). Estas prácticas promueven culturas éticas en los campos de la Ciencia, la Tecnología, la Ingeniería y las Matemáticas (en inglés *STEM—Science, Technology, Engineering, and Math*), y reconocen que el modelado 3D del patrimonio indígena es una parte fundamental de la conversación más amplia sobre la descolonización y las metodologías básicas. En este paper se propone incorporar las mejores prácticas desarrolladas a partir de las conclusiones del RCR a los proyectos de digitalización en 3D del patrimonio cultural indígena. Sugerimos la utilización de los principios de Beneficio Colectivo, Autoridad de Control, Responsabilidad y Ética (en ingles *CARE—**C**ollective benefit, **A**uthority to control, **R**esponsibility, and **E**thics*), la soberanía de los datos indígenas y un marco de coproducción de conocimientos (en ingles *CPK—co-production of knowledge*).

Keywords: 3D and related technologies; Indigenous data governance; ethics; Indigenous digital cultural heritage; co-production of knowledge; research equity; FAIR and CARE principles

Palabres clave: 3D y tecnologías relacionadas; gobernanza de datos indígenas; ética; patrimonio digital de la cultural indígena; coproducción de conocimiento; equidad en la investigación; principios FAIR y CARE

The rapid development and increased affordability of 3D technologies have enabled the integration of these tools into the daily lives of many technology users. The widespread availability of cellular and smartphone devices has accelerated and enhanced capabilities, with user-friendly applications enabling the creation of basic 3D digital models with minimal learning required. Moreover, sharing platforms facilitate the easy uploading and distribution of 3D content, allowing broad access to any data created. The resulting models are increasingly monetized, marketed, and sold through cloud-based platforms, catering to ecommerce, 3D printing and fabrication, and the gaming industry. These cloud-based techniques accelerate the advancement of artificial intelligence and its accessibility, which may have both positive and negative effects on Indigenous heritage and knowledges. While the sale and open sharing of such data and materials may be legally permissible, the ethical implications of many of these practices, especially using Indigenous materials and content appropriation, are controversial. For instance, while a museum may not explicitly prohibit photography of its exhibits, the resulting images can be used to create 3D digital models of Indigenous materials on display, thereby circumventing any consultation, discussion, or permissions. These models can then be swiftly uploaded, shared, and monetized as a gaming asset or used for fabrication design and physical replica production. In other scenarios, 3D models are developed and made freely available for download and distribution, often under the guise of open science. Although the 3D broker or researcher engaging in such activity does not necessarily violate any laws, these actions often disregard Indigenous cultural property rights and data sovereignty. The earlier example may seem hypothetical, but similar instances of 3D content brokering have been occurring in cyberspace for at least five years. Most museums lack specific regulations governing the creation and dissemination of 3D data. Even in cases where museums do regulate photography, enforcing such rules can be challenging, especially in an era when visitors carry smartphones, making it difficult to actively monitor exhibition spaces.

Not all museum visitors who create unauthorized 3D content do so with the intent to commercialize the models. The creation and open access (OA) sharing of 3D data and models have often been undertaken with the aim of "democratizing" data, making it accessible to all users, or returning digital data to members of the origin community from which the object originates (Kushner 2022). Notable examples include the unauthorized 3D replication of the Nefertiti bust (Machemer 2019) and the recent 3D scanning of the Elgin Marbles at the British Museum (Kinsella 2022; Lidz and Jones 2022; Mitchell 2023). The former refers to a highly detailed 3D scan of the 3,000-year-old bust of Nefertiti, which is in the collection of the Neues Museum in Berlin. Although the museum prohibited 3D scanning, a team of artists claimed to have covertly scanned the Nefertiti bust in a guerrilla scanning intervention. On closer examination, the data were deemed much higher quality than could be produced with guerrilla scanning, raising the possibility of a data leak from the museum. The Elgin Marbles were removed from the Parthenon in Athens and transported to England in the early 1800s by Thomas Bruce, the seventh Earl of Elgin. Lord Elgin claimed to have sought and secured permission from the Ottoman Empire to remove the collection. The Greek government has formally requested the return multiple times, which the British Museum has refused to date. Recently, it has been suggested that the British Museum should share the digital 3D data of the Elgin Marbles with Greece while it retains the physical counterparts. The practice of so-called guerrilla scanning, which involves expedient unauthorized data capture, is frequently done in museums using camera or smartphone photogrammetry methods with exhibited items to generate 3D models from 2D photographs. This practice is so popular in the 3D community that Sketchfab, an online platform described as the world's largest 3D-content hosting site, features a "guerrilla-scanning" tag for shared models of museum artifacts created through these means. Many of these models are also made available for downloading or monetized for sale from the Sketchfab Store, an organized collection on the platform (Sketchfab 2024).

The extent to which heritage institutions can claim copyrights over digital models and replicas of their collection pieces remains uncertain (Machemer 2019; Pittman 2020; Oruç 2020, 2022; Shein 2019; Weinberg 2016:1). The discourse generally revolves around the perspective that 3D digital images, although recognized as iterations of physical objects, are somewhat removed from their physical originals and the 3D data and resulting models can be used independently of the material counterparts (US Copyright Office 2014). This holds true whether the data are archived privately with limited or restricted access or made freely available in open-data repositories. The management and control of such data are typically governed or based on the creator-owner model, which assigns data ownership to the creator of the 3D data. This model is prevalent in current digital heritage preservation practices, particularly in European praxis, which firmly operates within the OA data framework and seldom engages with Indigenous data.

The 3D modeling of Indigenous heritage introduces issues of inherent ownership, access, and research ethics, complicating an already complex situation (see Table 1 for glossary). To fully and meaningfully engage with Indigenous collections through a digitization project, it is essential to acknowledge the colonial roots of ethnographic and archaeological collections. This acknowledgment is necessary to address enduring postcolonial legacies that present ongoing challenges for Indigenous origin communities. The principles of relationships and reciprocity are frequently highlighted as basic tenets of many Indigenous cultural systems (Brewer and Johnson 2023; Fienup-Riordan 2007; Fienup-Riordan et al. 2020; Kawerak 2021; Kovach 2010; Sanger and Barnett 2021; Shotton 2018; Smith 2021; Tsosie et al. 2021). By applying these core concepts to the interconnected ideas of tangible and intangible cultural heritage (Hassan 2014; UNESCO 2011; UNESCO Institute for Statistics 2009), we suggest that 3D digital models and their physical replicas can constitute an integral aspect of Indigenous cultural heritage.

In this article, we emphasize the importance of developing responsible conduct of research (RCR) guidelines that are tailored for 3D Indigenous heritage projects, grounded in the distinctions and applications of Indigenous Knowledge (IK) and Traditional Knowledge (TK). We recognize IK as a comprehensive knowledge system encompassing all Indigenous persons, whereas TK represents a specialized subset within this broader system, referring to specialized knowledge. To acknowledge the multiple types of knowledge that can be applied to better understand a phenomenon, we also use the plural term "knowledges." These principles align with the recommendations provided by Kawerak Inc., the Association of Village Council Presidents, the Tanana Chiefs Conference, the Aleut Community of St. Paul Island, the Kuskokwim River Inter-Tribal Fish Commission, and the Bering Sea Elders Group in their response to the White House Council on Environmental Quality (CEQ) and the White House Office of Science and Technology Policy (OSTP) regarding Indigenous Traditional Ecological Knowledge (Bahnke et al. 2022).

In formulating our project's RCR guidelines, we contend that collection pieces removed from their origin communities, and potentially unknown to those communities, retain Indigenous knowledge that can only be fully interpreted and understood within a culturally specific context. The process of knowledge repatriation highlights this by emphasizing the process of accessing Indigenous knowledges embedded in tangible and intangible cultural heritage, such as those held in museum collections. This reconnection creates opportunities for communities to reestablish links to their cultural and knowledge systems (e.g., Bell et al. 2013; Dawson et al. 2011; Kawerak 2018; Kirby-Straker et al. 2023). The digitization of Indigenous ancestral heritage generates data imbued with Indigenous knowledge, which falls under the Indigenous Data Governance (IDG) principles (Carroll et al. 2020; Hudson et al. 2023; Kukutai and Taylor 2016; Rainie et al. 2019; Walter and Suina 2018).

Table 1. Glossary.

Term	Definition
3D digital replica	A digital copy created by recording a physical model in 3D using laser, triangulation, or structured light scanning or photogrammetric techniques. These replicas only exist in digital space and can be used for education, analysis, visualization, and preservation.
3D physical replica	A tangible copy of the original created through 3D printing, milling, or other rapid prototyping or fabrication methods using a digital 3D data file as the source. These replicas represent the geometry, shape, and appearance of real-world objects. 3D physical replicas may also combine digital and nondigital techniques.
3D and associated technologies	Tools and methods used for creating, manipulating, and displaying 3D data, including 3D laser scanning, 3D printing, virtual reality (VR), augmented reality (AR), and more. These are used across industries for visualization and analysis.
Augmented reality (AR)	This technology allows for the overlay of digital information for visualization of digital content in the physical world. Digital information (such as images, videos, and 3D models) is viewed using devices such as tablets, smartphones, or glasses that enhance perception and understanding of physical environments or surroundings.
Born-digital content	Materials originally created in digital form, such as digital documents, 3D models, images, videos, and datasets, distinct from digitized content converted from analog formats.
CARE Principles	Principles for Indigenous Data Governance emphasizing **C**ollective Benefit, **A**uthority to Control, **R**esponsibility, and **E**thics, ensuring that Indigenous communities control their own data.
Co-production of knowledge (CPK)	Collaborative knowledge creation processes that bring together diverse perspectives (e.g., Indigenous and non-Indigenous) to achieve a more holistic and synergistic understanding and strengthen research outcomes.
Creator-owner model	An approach to data ownership assigning copyright to the individual or entity that creates the data, which may conflict with IDG (see Indigenous Data Governance).
Culturally sensitive data	Information with specific cultural significance requiring culturally responsive handling, sharing, and archiving to respect the values, practices, and traditions of the communities to which it belongs.
Data access	The ability to retrieve and use data, typically controlled by policies and permissions pertaining to data security and ethical use.
Data democratization	The process of making data widely accessible with limited to no restrictions. It can present challenges with misuse or misappropriation and may conflict with IDG (see Indigenous Data Governance).
Data degradation or deterioration or decay	The loss or corruption of data integrity over time due to factors such as storage degradation, format obsolescence, and inadequate software or hardware upgrades, particularly relating to digital information stored on physical devices.
Data neutrality	Impartial management of data to ensure usability without being tied to specific proprietary software or hardware applications, ensuring that data are broadly accessible with future-proofing considerations for sustainability.
Data reuse	The practice of using existing data for new research purposes or applications beyond the original intent.
Data stewardship	Responsible management and oversight of data assets, ensuring quality, accessibility, and security throughout the data life cycle, including practices such as data governance and preservation.
Digital repatriation	The practice of sharing digitized or born-digital data of Indigenous heritage with their Indigenous origin communities; can serve as a step in the process of physical repatriation but does not replace it.
Digitized content	Materials converted from analog formats (e.g., paper documents, photographs) into digital formats, enabling sustainable storage, retrieval, discoverability, and access.
Emerging technologies	Innovative advancements currently in development or expected in the near future (e.g., AI, generative AI) with the potential to affect the heritage sector.

(*Continued*)

Table 1. Glossary. (*Continued.*)

Term	Definition
eXtended reality (XR)	An umbrella term encompassing virtual reality (VR), augmented reality (AR), and mixed reality (MR), referring to the collective use of technologies to merge the physical and digital worlds for immersive experiences.
FAIR principles	Practices upholding that data are **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable, improving research efficiency, data management, and data usability.
Generative artificial intelligence (GAI)	AI algorithms or machine cognition used to produce new content (e.g., images, videos, text, geospatial data) based on training data with implications for heritage applications.
Global Indigenous Data Alliance (GIDA)	An international collective advocating for Indigenous peoples' rights in data stewardship, governance, and use, promoting ethical data management aligned with Indigenous values and interests globally.
Guerilla scanning	Unauthorized 3D data capture from objects or sites, often in museums or heritage sites, typically shared freely as downloadable files that are open access or monetized online.
Heritage preservation and perpetuation	The protection, preservation, and contemporary use of tangible and intangible cultural heritage for future generations, involving safeguarding and ongoing application by Indigenous origin communities of material heritage, traditions, and knowledge using various approaches and tools.
Indigenous Data Governance (IDG)	The right and authority of Indigenous Peoples and Tribal Nations to govern how data including Traditional Knowledges, Indigenous Knowledges, and Traditional Ecological Knowledges originating from their ancestors, communities, personal observations, lands, waters, and ecosystem, are accessed, managed, and used.
Indigenous Data Sovereignty (IDS)	The right and authority of Indigenous Peoples and Tribal Nations to control how existing and future data, including Traditional Knowledges, Indigenous Knowledges, and Traditional Ecological Knowledges, originating from Indigenous communities and Tribal Nations, their ancestors, communities, personal observations, lands, waters, and ecosystems, are accessed, managed, and used.
Indigenous Knowledge (IK)	A comprehensive knowledge system, including Traditional Knowledges, held by all Indigenous peoples (also see Traditional Knowledge).
Indigenous origin communities	Contemporary Indigenous communities maintaining direct connections to lands, traditions, and heritage in the past, present, and continuity.
Indigenous research protocols	Research protocols created by Indigenous communities ensuring that research engaging with their communities respects their rights, knowledge, and customs and complies with their policies.
Intangible heritage	Nonphysical aspects of culture, such as knowledge, storytelling, oral histories, performing arts, gastronomy, and other social practices that are integral parts of cultural heritage and identity.
Integrated approach to 3D documentation	Combining various technologies and methodologies to create comprehensive digital records of objects or sites, ensuring detailed and accurate data recording and representation.
Knowledges	The plural of knowledge, recognizing the validity of multiple types of knowledge systems, understanding, and expertise from diverse cultural perspectives.
Knowledge repatriation	A reassertion and reclamation of Indigenous epistemological, ontological, and axiological knowledges based in place, those knowledges being locations of Indigenous sovereignty. Knowledge repatriation takes place in the community and may include activities such as repatriation of cultural heritage items, documents, stories, etc.
Laser scanning	A noncontact method using a laser to measure distances and produce accurate 3D representations of surfaces.
Long-range laser scanning	Refers to the use of terrestrial laser scanning to record detailed surface data, textures, and measurements of 3D features, such as architecture, natural landscapes, and topography.

(*Continued*)

https://doi.org/10.1017/aaq.2024.82 Published online by Cambridge University Press

Table 1. Glossary. (*Continued.*)

Term	Definition
Metadata	Information about data and the context of creating the data (e.g., source, format, usage rights) essential for data management, understanding, and retrieval, with standards guiding necessary documentation.
Mixed reality (MR)	Technology combining real and virtual worlds to create new environments where physical and digital objects coexist, enabling real-time interaction.
Open access (OA)	Freely accessible research outputs distributed online, often with no or minimal restrictions, allowing users to read, download, and reuse content without any limitations.
Photogrammetry	A process using cameras to acquire multiple sets of overlapping images, enabling 3D information extraction and model creation from the photographs.
Research equity	Ensuring fair treatment, opportunities, and resources for all researchers and participants, addressing inequalities in the research process.
Responsible conduct of research (RCR)	Adherence to ethical and professional standards in research, including honesty, integrity, and accountability.
Short-range scanning	Scanning methods used over limited distances, enabling high-resolution data acquisition for in-depth surface analysis of objects; can include structured light scanning and triangulation instruments to record accurate point measurements.
Software obsolescence	The process of software becoming outdated and unsupported as new versions are released, requiring updates or replacements.
Structured light scanning	A 3D scanning technique using projected light patterns to record an object's shape, providing highly accurate results and fast data acquisition. Consideration of material properties, including reflectivity, movement potential, transparency, and color, is needed to maintain accuracy.
Sustainable data management	Ensuring long-term data preservation, curated maintenance, accessibility, and usability through proper planning, best practices, and resource allocation.
Tangible heritage	Physical artifacts, structures, monuments, and sites of cultural, historical, or archaeological significance.
Traditional Knowledge (TK)	Specialized knowledge, innovations, values, and practices of Indigenous communities, developed through intimate knowledge of, and relationships to, their environments (see also Indigenous Knowledge).
Virtual reality (VR)	Immersive digital environments simulating real or imagined worlds, experienced through a headset or similar device, replacing the user's physical surroundings with a virtual experience.
Virtual repatriation	An obsolete, noncollaborative method of sharing virtual replicas of Indigenous heritage with origin communities without the sharing of any physical or digital data of heritage and without meaningful collaboration with the origin communities.

This underscores the importance of culturally sensitive approaches and the application of RCR guidelines to ensure that Indigenous perspectives and rights are fully respected and integrated into practice.

3D technologies, whether focusing on digital or physical replicas, can play a pivotal role in knowledge repatriation, including offering new means of access to cultural and ancestral heritage for all community members (Acke et al. 2021; Magnani et al. 2019; Pittman 2020; Schmidt 2016; Watterson and Hillerdal 2020). These technologies provide community members with opportunities to develop personal experiences and connections with their ancestral heritage. Additionally, 3D technologies can assist in creating and actively curating opportunities for self-representation (Csoba DeHass and Taitt 2018; Harris 2017; Hollinger et al. 2013; Magnani et al. 2018), supporting communities in reclaiming and reintegrating knowledges previously separated from them. Recognizing the significance of 3D data as a carrier of Indigenous knowledges requires a shift from established practices rooted in the creator-owner model and advocating for the involvement of Indigenous creators in evolving capacities. This paradigm shift promotes a new framework that recognizes 3D digital data as an integral component of Indigenous knowledge. This new approach is focused on promoting equity in research, particularly data access, management, and reuse. It involves reframing 3D data of Indigenous heritage as an ongoing dialogue with Native Nations to determine the specific origin communities' heritage preservation and perpetuation goals.

Successful knowledge repatriation projects hinge on establishing and growing long-term relationships with Indigenous communities grounded in reciprocity and respect. A crucial yet often overlooked element of respect requires engaging with Indigenous communities from the the project's planning phase to avoid presumptive assumptions regarding data creation, access, and sharing in a collaborative 3D process. For example, data access levels can vary significantly from access restricted to origin community members to freely shared OA data available for download and reuse. There are examples of both approaches in practice, and it is essential to recognize that each community will make data access decisions based on its own needs, goals, and concerns (e.g., Hollinger 2019, 2022; Hollinger et al. 2013; Isaac 2015; Selden et al. 2014). Similarly, as part of the data creation process, communities can decide what should and should not be digitally documented, modeled, and archived. This decision could include considerations for human remains, sacred or funerary objects, and objects of cultural patrimony, among other culturally sensitive items.

IDG empowers communities to make decisions regarding their own heritage and peoples, including their ancestors. We advocate for a more holistic role for 3D researchers, which includes acting as advisers who can provide insights into the appropriateness of technology selection, archival preservation, and the known challenges, risks, and benefits of a 3D digital strategy. This advisory role supports communities in making informed decisions regarding their own heritage preservation and perpetuation goals. For this reason, the responsibility extends to offering specialized services and skills through collaborative involvement on request, providing training in working with Indigenous communities using 3D technologies in digital heritage preservation and perpetuation projects, ethically engaging with community members regarding 3D and related applications for digital technologies, and, whenever possible, assisting in training the next generation of early career researchers and community members in these applications and technologies.

Capacity, along with means and ability building, are integral tools in the co-production of a knowledge framework designed to promote equity in research (Ellam Yua et al. 2022). Co-production of knowledge (CPK) is the equitable process of integrating multiple ways of knowing to achieve a more holistic and synergistic research outcome (Figure 1). Although CPK can be implemented across various disciplines (e.g., Miner 2023; Norström et al. 2020; Redman et al. 2021; Schneider et al. 2021), we emphasize and echo the definition put forth by Ellam Yua et alia (2022) as it relates explicitly to co-production with Indigenous ways of knowing that can be applied to any discipline, including heritage preservation. In their article "A Framework for Co-Production of Knowledge in the Context of Arctic Research," the authors present a model for integrating Indigenous CPK and Western science disciplines, offering tools and strategies for diverse stakeholders to achieve equitable research. The historical context of research in the Arctic is steeped in colonial and racist ideologies that simultaneously devalued Indigenous knowledges and positioned Indigenous peoples as "the cultural other" whose knowledge had to be extracted for scientific purposes, thereby relegating Indigenous collaborators to the perpetual role of "informant."

In contrast, CPK aims to disrupt these postcolonial legacies cemented into research processes by offering a framework emphasizing trust, respect, empowerment, decolonization, and relationship building as cornerstones of working with Indigenous communities. CPK provides opportunities to examine, reflect on, and dismantle outdated research structures and to opt for equity in collaboration. The CPK framework's core tenets of supporting equity in research and the ongoing paradigm shift that focuses on establishing IDG as the norm in all research are aligned closely with our project's goals in outlining RCR guidelines that can be incorporated into future 3D heritage preservation and perpetuation projects.

We intentionally structured this project to bring together collaborators with extensive experience with 3D technologies and specialized knowledge in various aspects of digital heritage preservation and perpetuation. Our 14-member team includes both Indigenous and non-Indigenous members

https://doi.org/10.1017/aaq.2024.82 Published online by Cambridge University Press

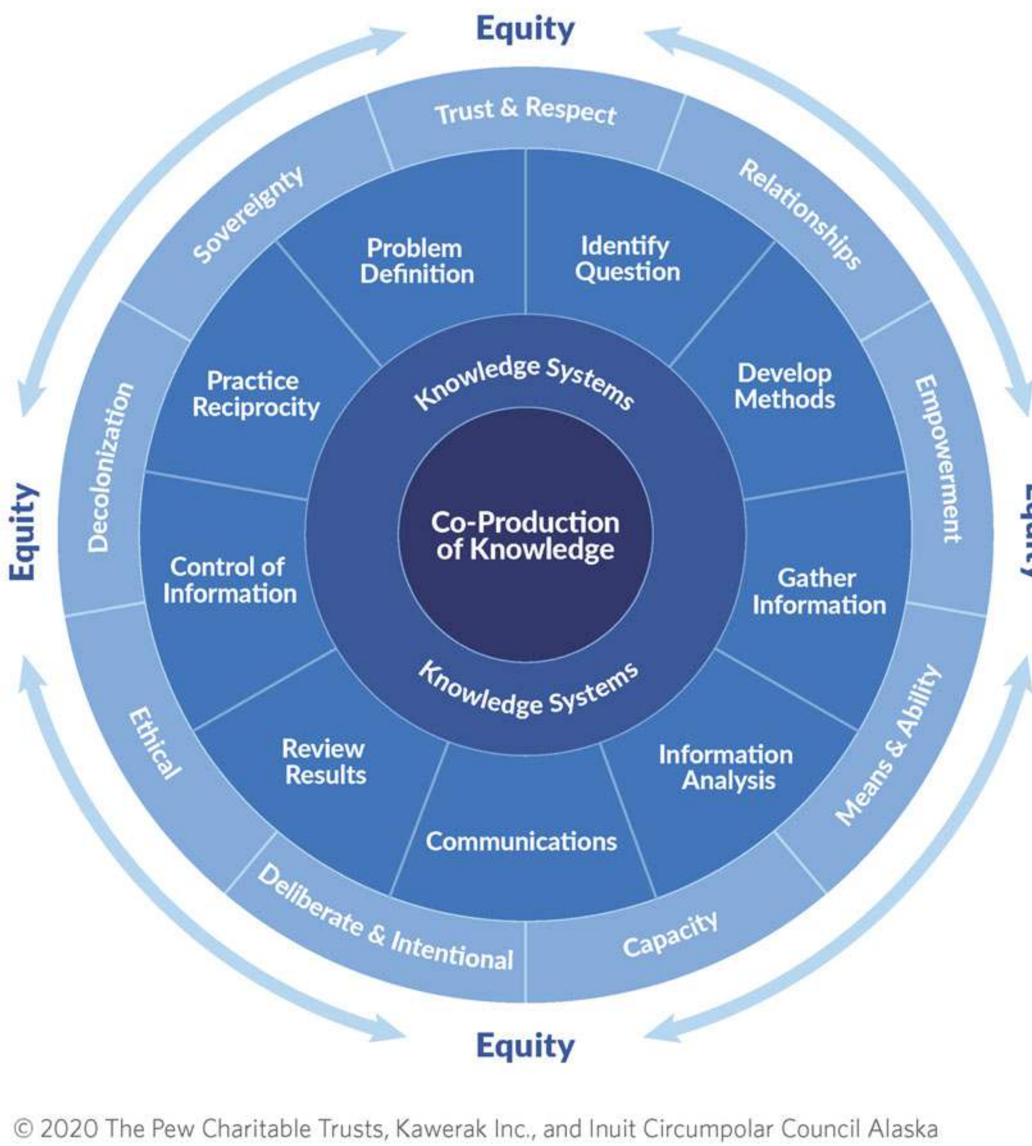

Figure 1. Co-production of knowledge framework (Ellam Yua et al. 2022).

with diverse backgrounds in museum management, archaeology, anthropology, 3D technologies, community engagement, and CPK practices. Although our project does not directly engage in 3D digitization work, it was nonetheless essential to include team members with extensive experience in 3D and related technologies. This expertise is crucial for understanding and conceptualizing digitization concepts and emerging technologies, as well as the potential use and misuse of 3D data (Collins et al. 2019). All team members bring multiple identities to our discussion, allowing us to draw on our past experiences in digital heritage preservation and perpetuation, computer science, repatriation, and working with Indigenous communities to synergistically explore the ethical use of 3D technology to engage with Indigenous cultural heritage.

Although we bring a variety of backgrounds and experiences gained while working with specific Indigenous communities and cultures, we do not intend to project these Indigenous perspectives to all past, current, and future 3D collaborations. Our approach centers on providing information on potential benefits, concerns, and challenges we identified during our previous work and projects (Figure 2).

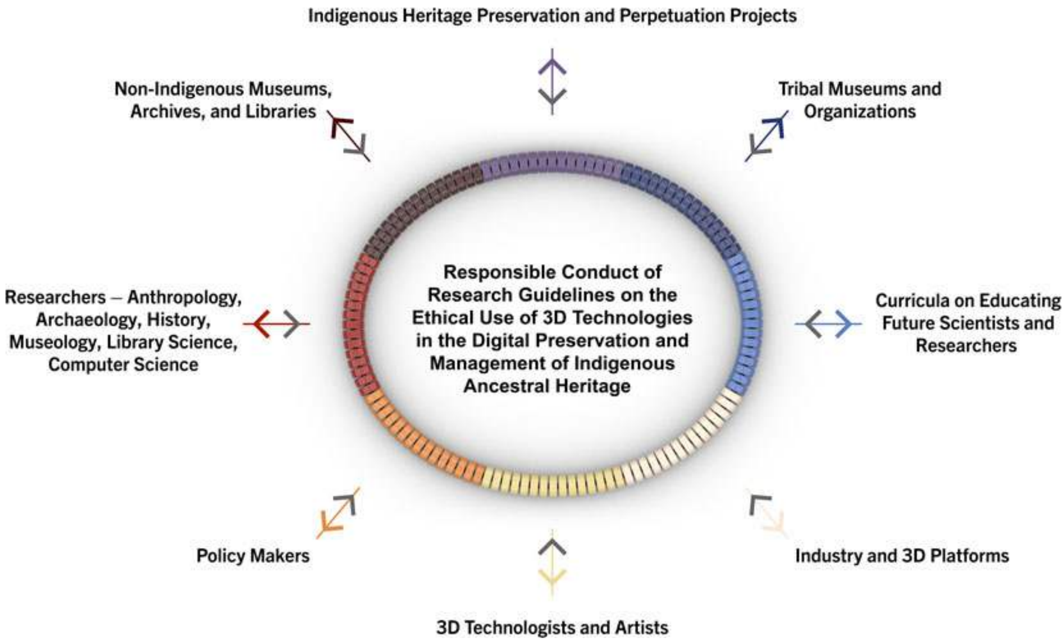

Figure 2. Responsible Conduct of Research Guide project outcomes.

We place this accumulative knowledge within the CPK framework to assist Indigenous and non-Indigenous institutions, researchers, and community members in interpreting these recommendations. This will empower them to make informed decisions that align with their specific needs, goals, and outcomes. What may work for one community may be completely unacceptable to another. We deliberately avoid the one-size-fits-all OA data approach often promoted under the guise of data democratization. Implementing a completely open data policy approach for digital heritage projects without Indigenous input would perpetuate colonial practices and can expand postcolonial legacies into digital and virtual spaces. We concur with Rainie and colleagues (2019) that the most effective way to address open-data challenges is through IDG and Indigenous Data Sovereignty (IDS). This approach provides a means to assist Indigenous communities in asserting their rights to own, control, access, and manage data that are related to their peoples, cultures, and knowledges while honoring their inherent sovereignty, self-determination, and values.

The paradigm shift and guidance we propose deviate from the well-established European body of literature on 3D heritage preservation that promotes an OA approach (e.g., Anichini et al. 2020; Ekengren et al. 2021; Europeana 2024; Fernández-Palacios et al. 2017; Guntram 2021; Ho 2023; International Council on Monuments and Sites [ICOMOS] 2024; Ioannides et al. 2018) as we are exploring areas of data sovereignty and examining how to translate their use operationally. The European praxis heavily focuses on digitizing well-known cultural symbols of national heritage. It uses open data as an aspect of self-representation, promoting a shared, universal concept of heritage that aims to be accessible to all potential users. In contrast, digitizing Indigenous heritage without input from the specific origin communities is essentially the opposite process because it represents another nation's heritage and values. In the United States, the 3D digitization of the ancestral heritage of Native Nations has highlighted the urgent need for an RCR guide. This guide is critical to addressing persistent concerns regarding data access and sharing, data reuse and repurposing, community consultation, data standards, and the future appropriateness and ethical use of 3D technologies in the context of Indigenous heritage.

Historical Context of 3D Technology in the Heritage Sector

The literature on 3D technology and heritage studies began to emerge in Europe, particularly in Italy, in the early 2000s (e.g., Balsamo et al. 2006; Pedersini et al. 2000; Pieraccini et al. 2001).

https://doi.org/10.1017/aaq.2024.82 Published online by Cambridge University Press

For the next decade, the publication output by Europe-based practitioners steadily increased, focusing primarily on the technical side of producing high-quality 3D models (e.g., Corns and Shaw 2009; García García et al. 2007; Pavlidis et al. 2007; Pieraccini et al. 2001; Yilmaz et al. 2007). The expansion of 3D research outside Europe to New Zealand, Australia, Canada, and the United States engendered a change in emphasis from heavy technical content to articles that reflect on the social relevance and importance of 3D modeling for the heritage sector (e.g., Dawson et al. 2011; Hollinger 2022; Hollinger et al. 2013; Hunter and Gerber 2010; Were 2014; Younan and Treadaway 2015). Between 2010 and 2016, our metanalysis of published literature shows a surge in the number of articles, with a significant increase in new projects showcasing the increased accessibility of 3D technology in the cultural sector.

The year 2017 marked a pivotal time for the application of 3D technology to heritage projects. Following this proliferation in projects and the subsequent data and knowledge gained through application, the discourse made a slow but clear shift toward publications and project reports that explored access, collaboration, and ethical concerns of 3D modeling cultural heritage, as well as the appropriateness of technological approaches employed (Collins et al. 2019; Haukaas and Hodgetts 2016; Richards-Rissetto and von Schwerin 2017; Thompson 2017). While some articles did explore the use of 3D technologies in relation to Indigenous communities during this period, most projects and discussions focused on regions where Indigenous communities were actively involved in culture-specific digital initiatives, such as New Zealand, Australia, Canada, and parts of the United States (Brown 2008; Hollinger 2022; Hollinger et al. 2013; Schmidt 2016; Surendran et al. 2009; Watterson and Hillerdal 2020; Were 2014). Much of the literature on 3D modeling and heritage preservation has primarily concentrated on the technical aspects of creating digital 3D models, including experimental methods to create highly realistic results, workflows, and guides for model refinement (e.g., Acke et al. 2021; Campanaro et al. 2016; Higueras et al. 2021; Ioannides and Patias 2023; Santana Quintero et al. 2019; Sequenzia et al. 2021; Wachowiak and Karas 2009; Wefers et al. 2017). Despite an increasing demand for ethical considerations in the development of emerging 3D technologies such as the integration and use of artificial intelligence (AI) and generative artificial intelligence (GAI) with 3D modeling (e.g., Bruncevic 2024; Pavlidis 2023; Pansoni et al. 2023), the current literature lacks a comprehensive analysis of the potential consequences of misuse. These consequences include the unintended use of data for fabrication and replication of physical objects or the unethical repurposing of Indigenous 3D data. Addressing this gap is essential to ensure that technological advancements are pursued responsibly and ethically.

An emphasis on technology has been present in the European tradition since the earliest studies, and it remains the focus of most 3D heritage preservation papers today (e.g., Balletti and Ballarin 2019; Bossema et al. 2023; Campiani et al. 2023). This is understandable, because it made sense to explore and document the capabilities of the new digitization technologies in the heritage preservation context and to fine-tune, streamline, and share workflows that would yield increasingly more accurate and reproducible results. At the same time, the shift from merely exploring technological capabilities to investigating the more extensive societal effects of these technologies has been slow to emerge (Magnani et al. 2020). Most papers that focus strictly on the technical side of 3D often have little to no consideration for the social and ethical impacts that 3D technology can have on cultural heritage. Articles and white papers that have considered the holistic view of 3D for heritage applications predominantly discuss collaboration, data ownership, and ethics. Still, they may not have been intended explicitly to meet Indigenous needs (e.g., Collins et al. 2019). A subset of these articles and papers attempt to address Indigenous communities (e.g., Brown 2008; Csoba DeHass and Hollinger 2018; Csoba DeHass and Taitt 2018; Dawson et al. 2011; Hollinger 2022; Hollinger et al. 2013; Magnani et al. 2018, 2023; Were 2014). Although there is a clear need for more studies in this area, these existing works provide crucial insights into using 3D and related technologies that respect and benefit Indigenous communities. Integrating these discussions and approaches is essential for developing comprehensive guidelines addressing both technical and ethical considerations.

Examples of noteworthy Indigenous 3D efforts include the Te Ataakura project, which was one of the first 3D projects done by, for, and with the Indigenous Māori of New Zealand, emphasizing cultural revitalization and honoring the intrinsic/intangible culture found in physical pieces of heritage (Salmond 2012). The Tlingit and Smithsonian partnership with the Killer Whale Hat digitization and replication project resulted in a physical and digital collaboration in which the original hat was repatriated to the clan that owned it. The clan later returned with the hat to have it digitized and a 3D physical replica made to remain at the Smithsonian for exhibition and education (Hollinger et al. 2013). These two early yet vastly influential projects demonstrated how 3D digital technology can transform the relationship between museums and Indigenous communities by assisting with returning knowledge and cultural heritage to communities. Awareness of the ethical concerns surrounding Indigenous cultural heritage is imperative. As we work with Indigenous communities to realize their visions of heritage preservation and perpetuation, we must be diligent in our approach, considering previously noted ethical concerns (Csoba DeHass and Hollinger 2018; Csoba DeHass and Taitt 2018; Magnani et al. 2018, 2019, 2023).

In the past decade, digitization and the production of born-digital content, originating in a digital format context, have become central to the discourse regarding Indigenous heritage. Multiple discussions are taking place around Indigenous digital heritage and ethical engagement with Indigenous data outside the scope of 3D technology. Analysis of the literature shows emerging concerns with technologies relating to AI (Lewis 2020), with examples of community-engaged research, the co-production of knowledge (Ellam Yua et al. 2022; Sumida Huaman and Mataira 2019; Sylvester et al. 2020), and data sovereignty (Carroll et al. 2019; Hudson et al. 2023; Kukutai and Taylor 2016; Taiuru 2020; Tsosie et al. 2021). These Indigenous-led or Indigenous-centered research projects face challenges related to IDS and ownership protocols, highlighting the need for frameworks that respect and uphold Indigenous rights and perspectives in the digital realm.

Several promising new approaches have emerged, successfully disrupting a range of practices and processes that have historically embodied Indigenous data alienation and infringed on Indigenous people's rights to control their data (Exchange for Observations and Local Knowledge of the Arctic [ELOKA] 2023; Executive Office of the President 2022; Global Indigenous Data Alliance [GIDA] 2019; Indigenous Sentinels Network 2024). This perspective aligned with the GIDA initiative to create the CARE principles to accompany the FAIR (**F**indable, **A**ccessible, **I**nteroperable, **R**eusable) principles for scientific data (GIDA 2019) and to find a new approach to Indigenous science that recognizes and acknowledges IDG. These ongoing discussions communicate the need for a new research paradigm in which IDG and IDS are the norm and cornerstone of research ethics. Carroll and colleagues (2019:3) define IDS as "the right of Indigenous peoples and tribes to govern the collection, ownership, and application of their own data," and Rainie and coauthors (2019:300) define it as "the right of Indigenous peoples to control data from and about their communities and lands, articulating both individual and collective rights to data access and to privacy." The digital heritage field is particularly attuned to ethical concerns and a need to delineate best practices for using 3D and associated technologies and to understand the potential for misuse (Collins et al. 2019).

The Use of 3D and Relational Technologies

In general, unique challenges exist in using 3D and related technologies with heritage documentation. Concerns for accuracy, scale, completeness, best methods, cost, and expectations for representing cultural materials and desired outcomes are prioritized in all digitization projects. Nevertheless, when working with Indigenous heritage, those concerns extend beyond the choice and feasibility of technologies to include issues of privacy, ownership, security of data, and appropriateness of use, including potentials for reuse and remaking. In addition, ethical issues must be weighed in terms of benefit and risk to ensure respectful and responsible engagement with Indigenous cultural materials.

Advances are occurring rapidly in the availability and integration of multiscale applications using a variety of short and long-range laser scanning and close-range object imaging tools. Technologies brought together for a blended approach to documentation greatly extend capabilities for digitization projects (Figure 3; Collins et al. 2019; Forte 2016; Schindling and Gibbes 2014). Reality capture—the act of digitizing heritage with integrated multiple sensors—bring together a suite of 2D photogrammetric and 3D documentation tools, many of which are low cost and readily available using mobile device

https://doi.org/10.1017/aaq.2024.82 Published online by Cambridge University Press

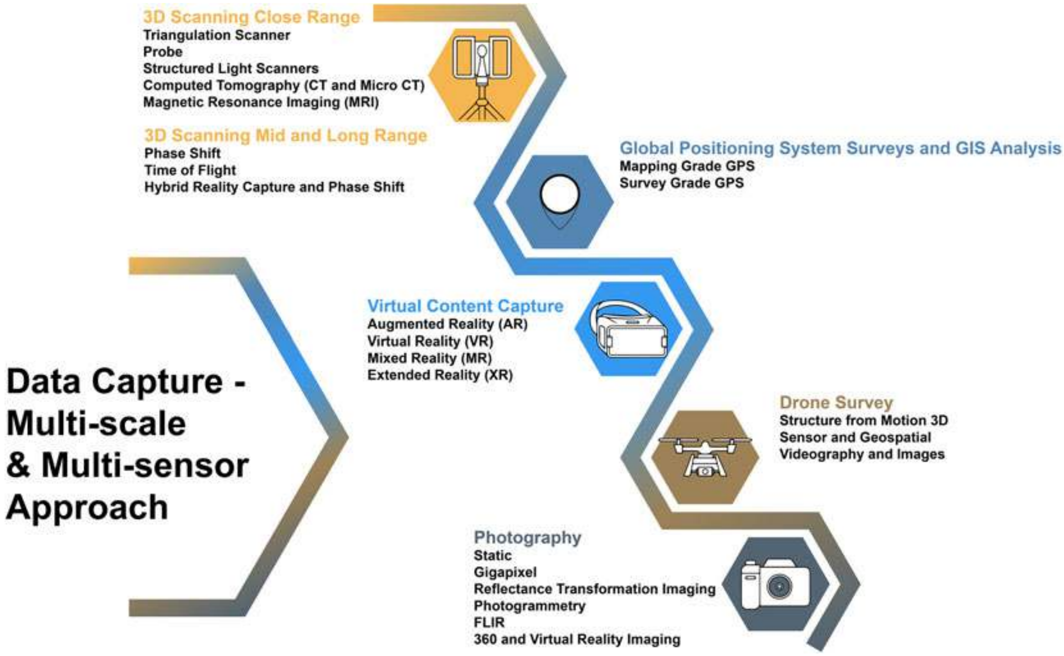

Figure 3. An integrated technology and multiscalar approach to 3D data acquisition.

applications. This approach leads to the broader adoption of 3D documentation and imaging of cultural objects, features, and landscapes.

Three-dimensional, geospatial, and imaging tools are also helping to increase data access and improve the ability to share, interpret, and digitally preserve Indigenous heritage and archaeological information. The ability to document the world around us rapidly and accurately is revolutionizing the fields of Indigenous studies, archaeology, museum studies, and library sciences. It is creating new areas of research, collection and curriculum development, and archival metadata standards. These technologies' applications create new cultural and natural heritage integration sectors and offer fresh approaches and opportunities for discovery, learning, and developing best practices for digital preservation, perpetuation, and archiving.

Still, one of the most challenging aspects of using 3D technology with heritage projects is considering its unintended consequences, especially in the context of emerging technologies. A long-standing critique of the rapid development in tech sectors is that it often outpaces the rate of awareness and consideration of ethical implications (Csoba DeHass and Taitt 2018; Sandler 2014). The potential exists for the misuse of information, which may promote looting, the inappropriate replication of objects, and ownership and security violations. These outcomes may lead to content appropriation in ways that do not align with the original digitization intent. Adequate safeguards for these ethical concerns start with understanding the full potential of these technologies and emerging future applications to avoid data misuse or mismanagement that conflicts with the intended purpose.

The inventive application of a newly emerging technology can be a double-edged sword. On the one hand, it creates a cutting-edge framework with potentially high rewards. On the other hand, it may simultaneously create an unexpected ethical conundrum. For this reason, the goal of our project is not to rigidly circumscribe the limits of ethical best practices when it comes to working with Indigenous heritage but to emphasize the need for early and continuous consultation with origin communities as the indispensable core of the co-production process.

Although there is a paucity of literature relating to the ethical consideration and understanding of 3D technologies specific to Indigenous heritage, Native Nations and heritage professionals are expressing growing interest in this topic. This will likely create a proliferation of projects and near-future case studies that will offer abundant learning opportunities to test further the existing state and limits of our understanding regarding IDG, IDS, and shared authority in 3D heritage projects (Harris 2017). The 3D engineering and science sectors are paying more attention to incorporating social and cultural considerations into the design of technology systems (Yong et al. 2023). These areas will also benefit from shared guidance development and case studies emerging from use applications. Each collaboration will produce a greater understanding of what data communities find sharable and how that data are conceptualized as part of Indigenous Knowledge systems. Additional use applications will continuously redefine the concepts of equitable access and ways of knowing and representing cultural heritage, helping make science more participatory and relevant to Indigenous communities.

Advancements in imaging and laser-scanning technologies, along with improved methods for using the data collected with these instruments and the increasing availability of mobile platforms such as drones for deploying these technologies, offer opportunities for positive applications with Indigenous cultural heritage. Emerging uses for these data—including replication; AI; virtual (VR), augmented (AR), and mixed (MR) reality; and extended (XR) media display and use—must be understood and aligned with ethical considerations to ensure their responsible implementation in Indigenous heritage documentation. Guidance in using the data, careful preservation, and concern for sovereignty, authority, and data protection issues must balance technical and methodological expertise before heritage data are broadly, and possibly inappropriately, disseminated and shared. Balancing technical and methodological expertise with these ethical concerns is crucial, with particular emphasis on future use and the potential for harm (Collins et al. 2019; Gish Hill and Csoba DeHass 2018; Hollinger and Partridge 2017; ICOMOS 2014; Santana Quintero et al. 2019).

When working with Indigenous materials and communities, it is important to consider technologies that best address the specific concerns and interests of the origin communities. All parties collaborating with Indigenous communities are responsible for discussing the benefits and possible risks of using 3D technologies to preserve Indigenous heritage. Collaboration beginning with the inception of a project will help create shared goals that can be revisited as the project evolves, ensuring that the appropriate 3D technology is used in support of the community's long-term heritage preservation and perpetuation goals.

It is also important to note that 3D and related technologies can be expensive to purchase and maintain, may become obsolete, and require regular upgrades and replacements. Collaborative approaches to capacity development can help manage these expenses. Developing cooperation among Indigenous groups, scholars, and 3D specialists can lead to more comprehensive and robust outcomes that address the needs for hardware, software, and methodological approaches and provide expertise in emergent applications for use, data management, metadata and archiving, and data preservation and access. Such collaborations can foster a deeper understanding of Indigenous data concerns and ensure the respectful and responsible handling of cultural heritage data.

Collaborating with Indigenous Communities on 3D Heritage Projects

Using 3D technologies with Indigenous heritage inherently differs from most other heritage praxis because it works with Indigenous Knowledge systems, often in a cross-cultural context. Consultation with origin communities is indispensable to the accurate representation and communication of the tangible and intangible Indigenous Knowledges embedded in the heritage pieces to be modeled. This is especially true when the items to be modeled are part of a collection at a public or private heritage institution that is not a Tribal institution but cares for Indigenous collections. It is essential to view digital models and potential 3D physical reproductions from these data as carriers of Indigenous or Traditional Knowledges embodied in the original pieces, rather than being separate, stand-alone creations. Designing all 3D projects through the principles of IDG is necessary, and consultation with Indigenous communities is the first step in creating a meaningful 3D preservation and perpetuation project.

Developing a working relationship with Indigenous communities takes time, often years, because it is a continuous interaction that centers building respect, trust, and a thorough understanding of reciprocity (Barlo et al. 2020; Ellam Yua et al. 2022; Nadasdy 1999; Wilson 2008). Lingering legacies of colonialism and their long-lasting effects are entrenched in research processes and hierarchies, and Indigenous communities are careful with their availability to participate in such projects (Smith

2021; Tuck 2009). Many Indigenous communities and Native Nations are proactive in establishing their own research protocols, oversight policies, and administrative units, with the specific goals of bringing about knowledge repatriation and establishing IDG as the building block of any research protocol that seeks to enter their communities (e.g., Alaska Federation of Natives 1993; Gwich'in Renewable Resources Board 2023; Hopi Cultural Preservation Office 2024; Inuit Tapiriit Kanatami and Nunavut Research Institute 2007; Kawerak et al. 2024; Kotzebue IRA 2024; Navajo Nation 2022; People of Kaktovik 1991; Turtle Mountain Band of Chippewa Indians Tribal Council 2014). Once the relationship is bilaterally developed with a robust mutual understanding of shared expectations, an ongoing discussion among research partners helps address inevitable changes and adjustments that emerge in technology-based 3D projects.

The CPK framework is particularly well suited for 3D heritage preservation work because it addresses many fundamental concepts and the tools needed to build and maintain a successful, reciprocal, and mutually beneficial relationship with Indigenous origin communities. Building on the definition of CPK by Ellam Yua et alia (2022:6), we view CPK as a research process that brings together multiple knowledge systems in partnership and equity to study the use of 3D technologies in preserving Indigenous heritage and to jointly develop a new understanding of the effects of 3D heritage preservation and perpetuation on those knowledge systems and conceptual frameworks. Although the CPK framework's conceptual tools are integral to the process, the following elements are particularly relevant to our project: Building and maintaining relationships, Deliberateness and intentionality, Equity, Capacity, and Means and ability. Drawing on the original definitions provided by Ellam Yua et alia (2022:4), we interpret these concepts in the context of 3D heritage preservation with Indigenous communities.

Building and maintaining relationships is central to all projects working with Indigenous communities. In 3D heritage preservation and perpetuation collaborations, creating and consistently maintaining these relationships early on are particularly important because such projects make materials that represent an Indigenous community, often in digital space (Gish Hill and Csoba DeHass 2018). CPK does not look any particular way. Some projects will have close and ongoing collaborations; others may set up specific milestones or outcomes to discuss project activities and results. On occasion, Indigenous communities may decline a project invitation and communicate their disapproval of a project using their data. Complying with this decision and accepting their "no" can be a successful co-production. The CPK process looks different in every case because all participants formulate the project together in a collaborative environment built on total equity in research without carried-over postcolonial research hierarchies. Although the CPK framework provides guidelines, it is up to the specific project participants to co-create their understanding of their working relationships and to define a successful 3D project. One of the most challenging parts of the CPK framework is creating processes built on sharing power, including decision-making power, among project participants. This power can take many forms in 3D heritage preservation projects, such as selecting pieces to be modeled, levels of openness in sharing 3D data, community review of project outcomes to be disseminated, or ongoing access to project 3D data. As CPK is built on bringing together and becoming familiar with multiple knowledge systems, creating and implementing research relationships includes a commitment to acknowledging the equal significance and contribution of knowledge systems and team members to the collaboratively defined project success.

The commitment of all participants to the shared effort is reflected in their **Deliberately and intentionally** becoming part of a project and contributing to the research process. Indigenous communities are invited to projects not as an afterthought but as key team members or initiators with real decision-making power in shaping the project. For these reasons, all participants must commit to intentional efforts to carry the team toward the collaboratively defined project outcomes. In 3D and related technology projects, this can translate to defining roles and responsibilities in creating and contextualizing 3D models, clearly communicating data management and archiving expectations, setting publication schedules, determining community expectations on deliverables, and clarifying processes for overcoming project obstacles. Developing working relationships that are built on trust and mutual respect takes time and careful effort.

https://doi.org/10.1017/aaq.2024.82 Published online by Cambridge University Press

For this reason, most projects that plan to address the complex task of using 3D and related technologies to preserve and perpetuate Indigenous heritage are built on preexisting relationships or start by investing appropriate time and resources to develop these relationships. Relationship building can consume time and resources, but it is necessary for research equity. In current practice, making the initial contact with Indigenous origin communities can be the biggest hurdle for many researchers. We recommend that researchers follow official communication channels with Tribes and Native Nations and be prepared to sincerely and meaningfully engage with the feedback, requests, and recommendations offered, even, or especially, when the response is a "no."

Just as the quality of the scientific research is continually assessed, research **Equity** must also be regularly revisited and evaluated. Doing so ensures that all participants are provided with the opportunities and resources needed to contribute to the project, thereby facilitating a co-designed approach. Establishing core principles and processes delineating how all team members understand research equity will help clarify questions and challenges throughout the project activities. Most projects will experience some setback or unexpected turbulence; usually this occurs when team members may prioritize problem solving over ensuring equity. In 3D research projects, there can be various pressures to quickly share 3D data and analysis results. These pressures could be due to a tight deadline, a change in an item's interpretation, or access restrictions. Building trust and equity as an essential aspect of the collaboration and continually revisiting these agreements help alleviate the pressures brought on by unexpected changes while providing a shared understanding for managing disputes.

Building capacity for all researchers, including community scientists, students, and 3D technologists, that specifically prepares them to work with Indigenous communities is critical to developing research equity. It can be gratifying to teach the next generation of scholars and technology users how to engage ethically in decolonization work that is respectful to Tribes and Native Nations. The interest in digitization, especially in 3D heritage work, has made these skills highly sought after in various careers. Although teaching co-production of knowledge frameworks is crucial in preparing students to work ethically with Indigenous communities and heritage, it is equally important to recognize the need for institutions to develop their own capacity to support equitable research recognizing Tribal sovereignty. This may require museums and universities to amend their policies on intellectual property and open data considerations, so that IDG is incorporated into all agreements and contracts that pertain to projects with Native Nations. Given that the capabilities of 3D and related technologies, as well as our understanding of their applications, are continually evolving, it is essential for all participants in 3D heritage projects to share the most current information on potential risks and benefits with partnering Indigenous communities. These considerations assist communities in making an informed decision on the type of 3D project, technology, and data management they wish to use to achieve their goals.

Just as capacity building prepares researchers and institutions to engage in processes based on equity in research, a consideration of **Means and ability** on the community level also needs to be a fundamental part of project development. In a broad approach, means and ability comes down to listening to what project partners, including Indigenous communities, need to be successful and equal partners in a specific project. This can include fair salaries or investment in training, facilities, or infrastructure on the local level. In 3D work, this can be a training developed explicitly for community-based heritage preservation professionals, including funds to purchase equipment for the communities so that community members can explore their approach to 3D technology, or it may be tailoring 3D project activities to community interests so that project sustainability does not depend on further and continued funding (Strathman 2019). As in capacity building, 3D heritage project team members are responsible for carefully listening to Indigenous communities' communications, articulating their needs for specific means and abilities, and meaningfully responding by adjusting project goals and activities. Maintaining a 3D technology lab is a major and ongoing investment in space, technology, updates, maintenance, and personnel. Although sometimes Indigenous groups may choose to build their capacity and infrastructure, investment can be minimized or optional when agreements and collaborative approaches can be made. In some cases, it may be more efficient for Indigenous communities to develop a strategy to help them ask the right questions when considering working externally

https://doi.org/10.1017/aaq.2024.82 Published online by Cambridge University Press

with 3D specialists and institutions for their projects. This approach will empower them to invest strategically in developing their own 3D expertise within the community or to select partners who maintain a respectful relationship and fully adhere to IDG principles.

The CPK framework is as much a commitment to research equity as it is to a research paradigm. CPK aims to bring awareness to equity issues that may be present in a particular field's praxis. In 3D heritage preservation, establishing relationships based on respect and equity in research relies on raising awareness about cultural property rights and data sovereignty concerns. With the increasing digitization of museum collections, specifically Indigenous cultural heritage, using 3D technologies, it is crucial to discuss the various nuances of 3D heritage technology, ethical considerations, and data management options. This will provide additional tools to Indigenous communities partnering or engaging in such projects to make an informed decision regarding their cultural heritage. At the same time, learning from these collaborative efforts is important so that more adaptable, flexible recommendations can emerge to support future projects. These experiences then in turn can address currently unforeseeable challenges stemming from the rapid advancement of 3D digital technology or a community's reevaluation of their approach to their digital data, data management practices, or heritage preservation and perpetuation goals.

Based on our experiences with 3D heritage projects and processes outlined in the CKP framework, we recommend three key considerations: (1) early and continuous community consultation, (2) clear workflow and data agreements, and (3) clarifying and outlining expectations, roles, compensation, and outcomes. Embracing the CPK approach requires collaboration that begins as early as the planning phase. Community consultation starts with shared planning and equal access to decision-making powers and mechanisms for all participants.

Establishing a partnership at the start of a heritage digitization project ensures that all stakeholders and collaborators will have their needs met from the beginning to the end of the project and into the future. It also establishes a precedent for open communication to discuss key factors such as 3D and associated data stewardship, dissemination and allowable format of results, culture-specific understandings of the project, and the project's significance in contributing to jointly articulated goals and expectations. In many projects with Indigenous communities, these conversations are not happening equitably. Far too often, research teams approach communities at a late stage in their project development, with goals and outcomes already established. They seem to be merely seeking a "silent partner" or a "seal of Indigenous approval" type of collaboration with Indigenous communities with little regard to the community's interests, needs, and input. Traditionally, these projects lack clear and ongoing communication once the data are collected. Although such research teams may occasionally return to present a small data segment or share reports at the end, they do not operate within the IDG framework. This approach has been the dominant paradigm in developing the creator-owner framework of 3D models in which 3D data are treated as the property of the person or project creating a model. This method perpetuates the alienation of Indigenous data and knowledge from origin communities and impedes their rights to self-representation and IDG. In addition to planning and negotiating goals, initial discussions are an opportunity to discuss plans for data stewardship, security, and ownership; how the data will be shared; and how to best disseminate the project results.

Integrating and sharing methods are significant aspects of many 3D projects. Although 3D specialists and technologists mainly create 3D models, it is important to provide training opportunities to community members to help them create 3D models for their use outside the scope of the specific project. This ongoing process of developing means, abilities, and capacity building is critical because it further reduces the barriers prevalent in traditional collaborative research methods. Providing access to the knowledge and technology to create and manage 3D models and sharing knowledge on the known and projected capabilities of 3D technologies actively contribute to decolonizing practices. Creating this access is also integral to the commitment to equity.

Data Stewardship

Three-dimensional scanning and photogrammetry are different but sometimes integrated methods of creating data that can be used to build 3D models. Each technology brings its own set of unique challenges. In photogrammetry, 2D photo sets are used to create the model, and these data can be used to produce 3D models when photographs are available for dissemination. Therefore, these photographic datasets, like 3D data, should be treated as potentially protected information. Similarly, in addition to finalized models and 3D datasets, raw format scans and individually registered and aligned 3D datasets from close- and long-range scanning that contain Indigenous information should be considered part of the data management plan, with the discrete portions of 3D and photogrammetric data collected seen as a carrier of Indigenous Knowledge and afforded a strategy for protection. Projects often treat Indigenous materials as different and interesting, using heritage as a case study for experimenting with new technologies without fully considering their cultural significance and stakeholders.

With the rise of GAI, it has become increasingly easy to obtain 3D models from online platforms without proper authorization. Unintended consequences and misappropriations can more easily occur as a result. Even when the data are unavailable for download, algorithms can automate the scraping or ripping of data uploaded to cloud-based servers to create high-quality models and potentially physical replicas from 3D data (Pagallo and Sciolla 2023). This unauthorized use and data theft can be decreased through metadata tagging, licensing restrictions, and prohibitions for use. However, seeking help from specialists and experts in data management is also recommended to enhance defenses against unintended or unauthorized data use.

Awareness of rapidly changing research landscapes is essential to research design and project management in all technology-centered projects. Access, sharing, and reuse issues need to be discussed, addressed, and periodically revisited for all 3D projects (Hardesty et al. 2020). When working on projects, it is important to have agreements in place that cover various aspects of data management. These agreements may include ownership details, access permissions during and after the project, data-sharing policies, and limitations on data usage such as restrictions on downloading or sharing. These discussions may result in mutual use agreements, permissions to process data, and establishing a level of clearance needed for a shared understanding of data security. It is essential to revisit data storage solutions and strategies periodically. Technology capabilities, software agreements, and project needs often require project teams to pivot and update their data management plans.

Decolonizing methodologies, which deconstruct Western scientific research by privileging Indigenous and Traditional Knowledge systems, has become a fundamental part of training future scientists. For this reason, it is understandable that most efforts are directed at decolonizing research processes so that new data collected will disrupt postcolonial legacies embedded in research processes. At the same time, decolonizing existing data is also a critical part of IDG and IDS. As Carroll and colleagues (2020:3) point out, “Indigenous data governance includes both the stewardship and the processes necessary to implement Indigenous control over Indigenous data (collection, storage, analysis, use, reuse).” In this sense, IDG addresses decolonizing data, data policies, data use, and data management that must be implemented to support Indigenous governance goals, including sovereignty (Carroll et al. 2019). We incorporate the concept of IDS in our RCR guidelines, as it provides a framework that prioritizes Indigenous interests and perspectives, ensuring the ethical use of Indigenous data through IDG. This approach places control of the entire data life-cycle process under the authority of Tribes and Native Nations (Walter and Suina 2018). Therefore, it is essential to consider strategies that implement IDG and IDS for managing existing Indigenous data, ensuring that communities maintain full authority and control.

When considering existing data, such as tangible and intangible knowledges associated with ancestral heritage in museum collections, it is vital to decolonize both the data’s representation and provenance. For example, considering the circumstances of data collection when contextualizing Indigenous data, such as the perspectives of those completing analysis and cataloging, is important in assessing the significance of the dataset from an Indigenous perspective in relation to specific project goals. At the same time, it is also essential from a data governance perspective because understanding the colonial framework in which the data were created and collected helps identify and construct decolonizing strategies that reestablish the data as a fundamental part of the Indigenous Knowledge framework. Decolonizing existing data is an integral part of IDG. It offers multiple points of engagement for researchers and Indigenous communities to formulate their shared data management goals that align with IDS and knowledge repatriation goals, as articulated by Indigenous origin communities.

For this reason, IDS counters many of the tenets of OA data sharing, often touted as a building block of open science (Berlin Declaration 2003; European Commission 2017; Europeana 2024; Hrynaszkiewicz 2021; Ramachandran et al. 2021; Roued-Cunliffe 2020; Scann 2019; Springer Nature 2024; UNESCO 2024). The OA and open data approaches emphasize and encourage the free availability and use of information(s). Open data approaches advocate for the FAIR principles of digital assets to make data easier to replicate in other research settings (Wilkinson et al. 2016). Although this may benefit some disciplines, OA data do not currently consider Indigenous people's rights, interests, and IDG goals. This is not to say that OA data solutions have no place in IDS. Reframing OA data praxis as a spectrum with different levels of access aligned with Indigenous interests helps better understand its potential compatibility with both IDS and IDG. Some Tribes and Native Nations may wish to make some of their data available in an OA format because it aligns with their IDG goals (Carroll et al. 2021). Others may wish to make specific datasets open access for educational use or to assert control over the digital representation of their cultures and communities. In this approach, OA is not automatically perceived as a challenge to data sovereignty but rather as a tool of IDG that is available to Indigenous communities to control and manage their own data.

To complement the FAIR principles while demonstrating more respect for IDS, the CARE principles were developed to align with the IDG paradigm (Carroll et al. 2020; GIDA 2019). According to GIDA, the CARE principles are "people and purpose-oriented, reflecting the crucial role of data in advancing Indigenous innovation and self-determination" (GIDA 2019) and pair with the FAIR principles to encourage others to consider the human side of data stewardship. When discussing OA concerns from the perspectives of IDG and IDS, the incompatibility of OA and sovereign data is often juxtaposed (e.g., Rainie et al. 2019; Walter and Suina 2018). However, when applying CARE principles to data access, the key is understanding the concept of "authority to control," which shifts the power dynamic away from researchers and to the hands of Indigenous communities. A carte blanche OA approach is counterproductive and harmful to Indigenous data, communities, and people. At the same time, reconceptualizing OA as a spectrum that gives a wide range of options to Indigenous communities, including accurate open access options, no longer poses a threat to IDS. OA can be used as one of many tools for communities to control their own data according to their cultural logic and expectations. It gives Indigenous communities the power to design and implement a data management praxis.

Conclusions

There is a need to continue developing and updating the RCR guidelines to keep pace with the evolution of 3D and emerging related technologies for preserving Indigenous heritage. Through the "Ethical Considerations in Three-Dimensional Digitization of Indigenous Heritage" project, we explored 3D modeling of Indigenous heritage as part of the larger discourse on decolonizing core methodologies while examining potential challenges and pitfalls that can jeopardize Indigenous perspectives and interests in 3D heritage preservation and perpetuation projects. The current praxis of the creator-owner approach is incompatible with working with 3D Indigenous heritage, because it negates the intangible Indigenous Knowledges embedded in physical heritage items and their digital replicas. This approach perpetuates a separation between Indigenous communities and their cultural heritage. It leads to blocking knowledge repatriation efforts and the origin communities' ability to exercise IDS over their data and incorporate their data into their own IDG framework.

To develop 3D projects that recognize IDS and prioritize research equity, it is important to work closely with communities in designing key outcomes that address their community interests and contribute to advancing science. The CPK framework provides a valuable approach on both theoretical and practical levels. Using the conceptual tools of Building and maintaining relationships, Deliberate and intentional, Equity, Capacity, and Means and ability, as described in the CPK framework, is particularly suitable for 3D heritage projects focused on Indigenous ancestral knowledges. By establishing respectful relationships built on an understanding of co-design and trust from the beginning, the project sets the stage for open communications that facilitate research equity for all contributors. This approach also supports the development of processes to revisit and refine established goals and expectations, especially when working with emerging and rapidly evolving technologies.

Understanding the capabilities and potential problems of 3D technologies and applications is a constant challenge that requires a continual learning process. Complementary technologies, such as AI, visualization, and data management platforms, interact with 3D technologies and can successfully contribute to technological solutions to achieve project goals when used cautiously. Although these technologies can offer significant advantages, they can also introduce new challenges, particularly because they often depend on proprietary control by software and hardware developers. Assembling and maintaining a 3D technology lab and the expertise required to operate one is time consuming and expensive. The rapid pace of technological advancement, with tools depreciating or becoming obsolete every three to five years, necessitates continual maintenance and updates, including typologies, data neutrality for future access, and sufficient data storage capacities. For this reason, investing in the technology, space, human capacity, and maintenance of a 3D lab that is capable of consistently producing high-quality 3D heritage work may not be the ultimate solution for many Indigenous communities and organizations. Rather, creating collaborations with partners and institutions well versed in working with Indigenous communities, IDG, IDS, and CPK, as well as fostering communities that are based on equity and respect, may be a more viable approach. This collaborative model can bring together diverse knowledges to address specific goals and outcomes effectively.

In addition to learning to collaborate through a CPK framework and bringing together areas of knowledge through a convergent science approach, a better understanding of the CARE and FAIR principles as they apply to data generated through 3D technologies is beginning to emerge. However, neither sustainable data management nor the reality of data deterioration and loss are resolved issues in heritage science and praxis. Roles for responsibilities and funding for managing and safeguarding Indigenous data collected through 3D projects are part of the ongoing discourse that needs to be reviewed within specific projects. As applications of 3D technologies in Indigenous heritage increase, it is important to continue developing our understanding of potential complications and ways to address them. The examination of ethics in Indigenous 3D heritage projects highlights the importance of understanding the role of 3D technologies through Indigenous Knowledge frameworks. Reflecting on the outcomes of these projects shows their potential to initiate a broader, structural change across all fields that deal with Indigenous data. These considerations, in turn, support IDG as an essential aspect of the research process.

Acknowledgments. We want to acknowledge our former project team members' contribution to our work: Joseph Conrad (University of South Florida), Aaron Lewis (University of South Florida), and Taylor Ross (Des Moines Area Community College). We acknowledge the contributions of Matthew Magnani (University of Maine) and Jelena Porsanger (Sámi Museum in Karasjok, RiddoDuottarMuseat; University of Helsinki), for sharing about their work. We also thank our anonymous reviewers for their thoughtful feedback.

Funding Statement. This work was supported by the National Science Foundation under grant numbers 2325183 and 2025744.

Data Availability Statement. No original data were used.

Competing Interests. The authors declare none.

References Cited

Acke, Lien, Kristel De Vis, Stijn Verwulgen, and Jouke Verlinden. 2021. Survey and Literature Study to Provide Insights on the Application of 3D Technologies in Objects Conservation and Restoration. *Journal of Cultural Heritage* 49:272–288. https://doi.org/10.1016/j.culher.2020.12.003.

Alaska Federation of Natives. 1993. Alaska Federation of Natives Guidelines for Research | Alaska Native Knowledge Network. Electronic document, https://www.uaf.edu/ankn/indigenous-knowledge-syst/alaska-federation-of-nati/, accessed February 23, 2024.

Anichini, Francesca, Francesco Banterle, Jaume Buxeda i Garrigós, Marco Callieri, Nachum Dershowitz, Nevio Dubbini, Diego Lucendo Diaz, et al. 2020. Developing the ArchAIDE Application: A Digital Workflow for Identifying, Organising and Sharing Archaeological Pottery Using Automated Image Recognition. *Internet Archaeology* 52. https://doi.org/10.11141/ia.52.7.

Bahnke, Melanie, Vivian Korthuis, Brian Ridley, Amos Philemonoff, Mike Williams Sr., and Fred Phillip. 2022. Tribal Coalition TK/ITEK Letter. Electronic document, https://kawerak.org/natural-resources/social-science/, accessed February 23, 2024.
Balletti, Caterina, and Martina Ballarin. 2019. An Application of Integrated 3D Technologies for Replicas in Cultural Heritage. *ISPRS International Journal of Geo-Information* 8(6):285. https://doi.org/10.3390/ijgi8060285.
Balsamo, Alessandro, Antonio Chimienti, Paolo Grattoni, Roberto Nerino, Giuseppe Pettiti, Maria Luisa Rastello, and Massimiliano Spertino. 2006. Active Vision Applications to Cultural Heritage Acquisition and Monitoring. *Journal of Cultural Heritage* 7(2):98–109. https://doi.org/10.1016/j.culher.2006.02.006.
Barlo, Stuart, William (Bill) Edgar Boyd, Alessandro Pelizzon, and Shawn Wilson. 2020. Yarning as Protected Space: Principles and Protocols. *AlterNative* 16(2):90–98. https://doi.org/10.1177/1177180120917480.
Bell, Joshua A., Kimberly Christen, and Mark Turin. 2013. After the Return: Digital Repatriation and the Circulation of Indigenous Knowledge Workshop Report. *Museum Worlds* 1(1):195–203.
Berlin Declaration. 2003. Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities. Electronic document, https://openaccess.mpg.de/Berlin-Declaration, accessed February 23, 2024.
Bossema, Francien G., Paul J. C. van Laar, Kimberly Meechan, Daniel O'Flynn, Joanne Dyer, Tristan van Leeuwen, Suzan Meijer, Erma Hermens, and K. Joost Batenburg. 2023. Inside Out: Fusing 3D Imaging Modalities for the Internal and External Investigation of Multi-Material Museum Objects. *Digital Applications in Archaeology and Cultural Heritage* 31:e00296. https://doi.org/10.1016/j.daach.2023.e00296.
Brewer, Joseph P., II, and Jay T. Johnson. 2023. Reciprocity: An Ethos "More than Human." *GeoHumanities* 9(2):315–332. https://doi.org/10.1080/2373566X.2022.2158899.
Brown, Deidre. 2008. "Ko to Ringa Ki Nga Rakau a Te Pakeha"—Virtual *Taonga* Maori and Museums. *Visual Resources* 24(1): 59–75. https://doi.org/10.1080/01973760801892266.
Bruncevic, Merima. 2024. Heritage Law in Relation to Art Law: From Object to Museum. In *The Routledge Handbook of Heritage and the Law*, edited by Lucas Lixinski and Lucie K. Morisset, pp. 46–60. Routledge, London.
Campanaro, Danilo Marco, Giacomo Landeschi, Nicoló Dell'Unto, and Anne-Marie Leander Touati. 2016. 3D GIS for Cultural Heritage Restoration: A "White Box" Workflow. *Journal of Cultural Heritage* 18:321–332. https://doi.org/10.1016/j.culher.2015.09.006.
Campiani, Arianna, Scott McAvoy, Nicola Lercari, Rodrigo Liendo Stuardo, Gerardo Jiménez Delgado, Javier López Mejía, Dominique Rissolo, and Falko Kuester. 2023. Developing an Interoperable Cloud-Based Visualization Workflow for 3D Archaeological Heritage Data: The Palenque 3D Archaeological Atlas. *Digital Applications in Archaeology and Cultural Heritage* 31:e00293. https://doi.org/10.1016/j.daach.2023.e00293.
Carroll, Stephanie Russo, Desi Rodriguez-Lonebear, and Andrew Martinez. 2019. Indigenous Data Governance: Strategies from United States Native Nations. *Data Science Journal* 18:31. https://doi.org/10.5334/dsj-2019-031.
Carroll, Stephanie Russo, Edit Herczog, Maui Hudson, Keith Russell, and Shelley Stall. 2021. Operationalizing the CARE and FAIR Principles for Indigenous Data Futures. *Scientific Data* 8:108. https://doi.org/10.1038/s41597-021-00892-0.
Carroll, Stephanie Russo, Ibrahim Garba, Oscar L. Figueroa-Rodríguez, Jarita Holbrook, Raymond Lovett, Simeon Materechera, Mark Parsons, et al. 2020. The CARE Principles for Indigenous Data Governance. *Data Science Journal* 19:43. https://doi.org/10.5334/dsj-2020-043.
Collins, Lori D., Travis Doering, and Jorge Gonzalez. 2019. *The Use and Potential Misuse of 3D and Spatial Heritage Data in Our Nation's Parks*. Center for Digital Heritage and Geospatial Information Collections Faculty and Staff Publications 21. Electronic document, https://digitalcommons.usf.edu/dhhc_facpub/21, accessed February 23, 2024.
Corns, Anthony, and Robert Shaw. 2009. High Resolution 3-Dimensional Documentation of Archaeological Monuments & Landscapes Using Airborne LiDAR. *Journal of Cultural Heritage* 10(S1):e72–e77. https://doi.org/10.1016/j.culher.2009.09.003.
Csoba DeHass, Medeia, and Eric Hollinger. 2018. 3D Heritage Preservation and Indigenous Communities in the Circumpolar North. In *Arctic Yearbook 2018*, edited by Lassi Heininen and Heather Exner-Pirot, pp. 218–232. Northern Research Forum, Akureri, Iceland.
Csoba DeHass, Medeia Krisztina, and Alexandra Taitt. 2018. 3D Technology in Collaborative Heritage Preservation. *Museum Anthropology Review* 12(2):120–153. https://doi.org/10.14434/MAR.V12I2.22428.
Dawson, Peter, Richard Levy, and Natasha Lyons. 2011. "Breaking the Fourth Wall": 3D Virtual Worlds as Tools for Knowledge Repatriation in Archaeology. *Journal of Social Archaeology* 11(3):387–402. https://doi.org/10.1177/1469605311417064.
Ekengren, Fredrik, Marco Callieri, Domenica Dininno, Åsa Berggren, Stella Macheridis, and Nicolò Dell'Unto. 2021. Dynamic Collections: A 3D Web Infrastructure for Artifact Engagement. *Open Archaeology* 7(1):337–352. https://doi.org/10.1515/opar-2020-0139.
Ellam Yua, Julie Raymond-Yakoubian, Raychelle Aluaq Daniel, and Carolina Behe. 2022. A Framework for Co-Production of Knowledge in the Context of Arctic Research. *Ecology and Society* 27(1):34. https://doi.org/10.5751/ES-12960-270134.
European Commission. 2017. *Guidelines to the Rules on Open Access to Scientific Publications and Open Access to Research Data in Horizon 2020 Version 3.2*. Electronic document, https://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-pilot-guide_en.pdf, accessed February 23, 2024.
Europeana. 2024. About. Electronic document, https://www.europeana.eu/en/about-us, accessed February 23, 2024.
Exchange for Local Observations and Knowledge of the Arctic (ELOKA). 2023. About ELOKA. Electronic document, https://eloka-arctic.org/about-eloka, accessed February 23, 2024.
Executive Office of the President. 2022. Memorandum on Recognizing and Including Indigenous Knowledge in Federal Research, Policy, and Decision Making. White House Council on Environmental Quality [CEQ] and the White House

Office of Science and Technology Policy [OSTP]. Electronic document, https://bidenwhitehouse.archives.gov/wp-content/uploads/2022/12/OSTP-CEQ-IK-Guidance.pdf, accessed February 23, 2024.
Fernández-Palacios, Belen Jiménez, Daniele Morabito, and Fabio Remondino. 2017. Access to Complex Reality-Based 3D Models Using Virtual Reality Solutions. *Journal of Cultural Heritage* 23:40–48. https://doi.org/10.1016/j.culher.2016.09.003.
Fienup-Riordan, Ann. 2007. *Yuungnaqpiallerput / The Way We Genuinely Live: Masterworks of Yup'ik Science and Survival*. University of Washington Press, Seattle.
Fienup-Riordan, Ann, Alice Rearden, Marie Meade, David Chanar, Rebecca Nayamin, and Corey Joseph. 2020. *Nunakun-Gguq Ciutengqertut / They Say They Have Ears through the Ground: Animal Essays from Southwest Alaska*. University of Alaska Press, Fairbanks.
Forte, Maurizio. 2016. Cyber Archaeology: 3D Sensing and Digital Embodiment. In *Digital Methods and Remote Sensing in Archaeology: Archaeology in the Age of Sensing*, edited by Maurizio Forte and Stefano Campana, pp. 271–289. Springer International, Cham, Switzerland.
García García, Francisco, Manuel Ramírez Blanco, Isabel Rodríguez Abad, Rosa Martínez Sala, Isabel Tort Ausina, Javier Benlloch Marco, and Jose Luis Montalvá Conesa. 2007. GPR Technique as a Tool for Cultural Heritage Restoration: San Miguel de Los Reyes Hieronymite Monastery, 16th Century (Valencia, Spain). *Journal of Cultural Heritage* 8(1):87–92. https://doi.org/10.1016/j.culher.2006.10.005.
Gish Hill, Christina, and Medeia Csoba DeHass. 2018. Digital Representation of Indigenous Peoples through Sharing, Collaboration, and Negotiation: An Introduction. *Museum Anthropology Review* 12(2):40–54. https://doi.org/10.14434/mar.v12i2.23540.
Global Indigenous Data Alliance [GIDA]. 2019. *CARE Principles for Indigenous Data Governance*. Electronic document, https://www.gida-global.org/care, accessed February 23, 2024.
Guntram, Geser. 2021. D2.3 Final Report on Community Needs (1.0). *ARIADNEplus – Advanced Research Infrastructure for Archaeological Dataset Networking in Europe*. Zenodo, October 29. https://doi.org/10.5281/zenodo.5647356, accessed February 23, 2024.
Gwich'in Renewable Resources Board. 2023. Research. Electronic document, https://grrb.nt.ca/traditional-knowledge-research/research/, accessed February 23, 2024.
Hardesty, Juliet L., Jennifer Johnson, Jamie Wittenberg, Nathan Hall, Matt Cook, Zack Lischer-Katz, Zhiwu Xie, and Robert H. McDonald. 2020. 3D Data Repository Features, Best Practices, and Implications for Preservation Models: Findings from a National Forum. *College & Research Libraries* 81(5):789–807. https://doi.org/10.5860/crl.81.5.789.
Harris, Larissa. 2017. The White Earth Digital Tribal Museum: Creation of an Open-Access Online Museum Using 3D Images of Cultural Heritage Objects. Master's thesis, Department of Anthropology, University of Manitoba, Winnipeg.
Hassan, Fekri. 2014. Tangible Heritage in Archaeology. In *Encyclopedia of Global Archaeology*, edited by Claire Smith, pp. 7213–7215. Springer, New York.
Haukaas, Colleen, and Lisa M. Hodgetts. 2016. The Untapped Potential of Low-Cost Photogrammetry in Community-Based Archaeology: A Case Study from Banks Island, Arctic Canada. *Journal of Community Archaeology & Heritage* 3(1):40–56. https://doi.org/10.1080/20518196.2015.1123884.
Higueras, María, Ana Isabel Calero, and Francisco José Collado-Montero. 2021. Digital 3D Modeling Using Photogrammetry and 3D Printing Applied to the Restoration of a Hispano-Roman Architectural Ornament. *Digital Applications in Archaeology and Cultural Heritage* 20:e00179. https://doi.org/10.1016/j.daach.2021.e00179.
Ho, Karen K. 2023. British Museum Will Digitize Entire Collection at a Cost of $12.1 M. in Response to Thefts. *ARTnews*, October 18. https://www.artnews.com/art-news/news/british-museum-digitize-collection-thefts-comments-parliament-1234683315/, accessed February 23, 2024.
Hollinger, Eric. 2019. Smithsonian Uses 3D Tech to Restore a Broken Sacred Object for Tlingit Indians. *SI Digi Blog*, September 23. https://dpo.si.edu/blog/smithsonian-uses-3d-tech-restore-broken-sacred-object-tlingit-indians, accessed February 23, 2024.
Hollinger, Eric. 2022. 3D Digital Replication: Emerging Cultural Domain for Native American Communities. In *Introduction*, edited by Igor Krupnik, pp. 182–195. Handbook of North American Indians Vol. 1, William C. Sturtevant, general editor. Smithsonian Institution, Washington, DC.
Hollinger, Eric, and Nick Partridge. 2017. Is 3D Technology the Key to Preserving Indigenous Cultures? *Smithsonian Voices* (blog), November 29. http://www.smithsonianmag.com/blogs/national-museum-of-natural-history/2017/11/29/3d-technology-key-preserving-indigenous-cultures/, accessed February 23, 2024.
Hollinger, R. Eric, Edwell John Jr., Harold Jacobs, Lora Moran-Collins, Carolyn Thome, Jonathan Zastrow, Adam Metallo, Günter Waibel, and Vince Rossi. 2013. Tlingit-Smithsonian Collaborations with 3D Digitization of Cultural Objects. *Museum Anthropology Review* 7(1–2):201–253.
Hopi Cultural Preservation Office. 2024. Protocol for Research, Publication and Recordings: Motion, Visual, Sound, Multimedia and other Mechanical Devices. Electronic document, https://naair.arizona.edu/sites/default/files/hopi_cultural_preservation_office_protocol_for_research_0%20%281%29.pdf, accessed February 23, 2024.
Hrynaszkiewicz, Iain. 2021. Wellcome Trust Awards PLOS a Grant to Test Ways to Increase Sharing and Discovery of Research Data. *Official PLOS Blog*, September 13. https://theplosblog.plos.org/2021/09/wellcome-trust-awards-plos-a-grant-to-test-ways-to-increase-sharing-and-discovery-of-research-data/, accessed February 23, 2024.
Hudson, Maui, Stephanie Russo Carroll, Jane Anderson, Darrah Blackwater, Felina M. Cordova-Marks, Jewel Cummins, Dominique David-Chavez, et al. 2023. Indigenous Peoples' Rights in Data: A Contribution toward Indigenous Research Sovereignty. *Frontiers in Research Metrics and Analytics* 8:1173805. https://www.frontiersin.org/articles/10.3389/frma.2023.1173805.

Hunter, Jane, and Anna Gerber. 2010. Harvesting Community Annotations on 3D Models of Museum Artefacts to Enhance Knowledge, Discovery and Re-Use. *Journal of Cultural Heritage* 11(1):81–90. https://doi.org/10.1016/j.culher.2009.04.004.

Indigenous Sentinels Network. 2024. About. Electronic document, https://www.sentinelsnetwork.org/about-1, accessed February 23, 2024.

International Council on Monuments and Sites (ICOMOS). 2014. ICOMOS Ethical Principles. Electronic document, https://www.icomos.org/images/DOCUMENTS/Secretariat/2015/GA_2014_results/20150114-ethics-asadopted-languagecheck-finalcirc_rev202012.pdf, accessed February 23, 2024.

International Council on Monuments and Sites (ICOMOS). 2024. ICOMOS Open Archive: EPrints on Cultural Heritage User Documentation. Electronic document, https://openarchive.icomos.org/help/#Copyright, accessed February 23, 2024.

Inuit Tapiriit Kanatami and Nunavut Research Institute. 2007. *Negotiating Research Relationships with Inuit Communities: A Guide for Researchers*. Edited by Scot Nickels, Jamal Shirley, and Gita Laidler. Inuit Tapiriit Kanatami, Ottawa; Nunavut Research Institute, Iqaluit. https://www.climatechangenunavut.ca/sites/default/files/nri_research_fyi_guide_2007_0.pdf, accessed February 23, 2024.

Ioannides, Marinos, and Petros Patias. 2023. The Complexity and Quality in 3D Digitisation of the Past: Challenges and Risks. In *3D Research Challenges in Cultural Heritage III: Complexity and Quality in Digitisation*, edited by Marinos Ioannides and Petros Patias, pp. 1–33. Springer International, Cham, Switzerland.

Ioannides, Marinos, Eleanor Fink, Raffaella Brumana, Petros Patias, Anastasios Doulamis, João Martins, and Manolis Wallace (editors). 2018. *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection: 7th International Conference, EuroMed 2018, Nicosia, Cyprus, October 29–November 3, 2018, Proceedings, Part II*. Springer International, Cham, Switzerland.

Isaac, Gwyneira. 2015. Perclusive Alliances: Digital 3-D, Museums, and the Reconciling of Culturally Diverse Knowledges. *Current Anthropology* 56(S12):S286–296. https://doi.org/10.1086/683296.

Kawerak. 2018. Katirvik Cultural Center. Electronic document, https://kawerak.org/cultural-development/katirvik-cultural-center/, accessed February 23, 2024.

Kawerak. 2021. *Knowledge and Research Sovereignty Workshop May 18–21 2021 Report*. Prepared by Sandhill.Culture.Craft and Kawerak Inc., Social Science Program. Nome, Alaska.

Kawerak, Chinik Eskimo Community, King Island Native Community, Native Village of Brevig Mission, Native Village of Council, Native Village of Diomede, Native Village of Elim, et al. 2024. *Kawerak-Region Tribal Protocols, Guidelines, Expectations & Best Practices Related to Research*. Prepared by the Kawerak Social Science Program and Sandhill.Culture.Craft. Nome, Alaska. Electronic document, https://www.kawerak.org/knowledge, accessed February 23, 2024.

Kinsella, Eileen. 2022. Could a Perfect 3-D Copy Solve the Quandary over Who Gets the Parthenon Marbles? An Oxford University Scholar Thinks So. *Artnet News*, August 8. https://news.artnet.com/art-world/parthenon-marbles-3-printed-2157443, accessed February 23, 2024.

Kirby-Straker, Rowie, Carrie Johnston, Kathy Shields, and Ron Von Burg. 2023. Academic Research and Knowledge Repatriation at the Intersection of Epistemic and Environmental Justice in the Caribbean. *Geographical Journal* 189(4):666–673. https://doi.org/10.1111/geoj.12516.

Kotzebue IRA. 2024. Native Village of Kotzebue Research Protocol. Electronic document, https://www.arcus.org/files/meeting/products/native_village_of_kotzebue_research_protocol_updated_july_2018.pdf, accessed February 23, 2024.

Kovach, Margaret. 2010. *Indigenous Methodologies: Characteristics, Conversations, and Contexts*. University of Toronto Press, Toronto.

Kukutai, Tahu, and John Taylor. 2016. *Indigenous Data Sovereignty—Toward an Agenda*. Centre for Aboriginal Economic Policy Research Monograph No. 38. Australian National University Press, Canberra.

Kushner, Jacob. 2022. Kenya Wants Its Treasures Back: Replicas Could Spur Their Return. *National Geographic*, June 21. https://www.nationalgeographic.com/history/article/kenya-wants-its-stolen-treasures-back-replicas-could-spur-their-return, accessed February 23, 2024.

Lewis, Jason Edward (editor). 2020. *Indigenous Protocol and Artificial Intelligence Position Paper*. Initiative for Indigenous Futures and the Canadian Institute for Advanced Research (CIFAR), Honolulu, Hawai'i.

Lidz, Franz, and Francesca Jones. 2022. The Robot Guerrilla Campaign to Recreate the Elgin Marbles. *New York Times*, July 8. https://www.nytimes.com/2022/07/08/science/elgin-marbles-3d-print.html, accessed February 23, 2024.

Machemer, Theresa. 2019. 3-D Scans of the Bust of Nefertiti Are Now Available Online. *Smithsonian Magazine*, November 22. https://www.smithsonianmag.com/smart-news/3-d-scans-bust-nefertiti-are-now-available-online-180973628/, accessed February 23, 2024.

Magnani, Matthew, Anni Guttorm, and Natalia Magnani. 2018. Three-Dimensional, Community-Based Heritage Management of Indigenous Museum Collections: Archaeological Ethnography, Revitalization and Repatriation at the Sámi Museum Siida. *Journal of Cultural Heritage* 31:162–169. https://doi.org/10.1016/j.culher.2017.12.001.

Magnani, Matthew, Natalia Magnani, and Anni Guttorm. 2019. Accessibility, Authenticity, and the Ethics of Digital Representation: A Reply to Galeazzi. *Current Anthropology* 60(2):262–263. https://doi.org/10.1086/702305.

Magnani, Matthew, Matthew Douglass, Whittaker Schroder, Jonathan Reeves, and David R. Braun. 2020. The Digital Revolution to Come: Photogrammetry in Archaeological Practice. *American Antiquity* 85(4):737–760. https://doi.org/10.1017/aaq.2020.59.

Magnani, Matthew, Jelena Porsanger, Sami Laiti, Natalia Magnani, Anne May Olli, Paula Rauhala, Samuel Valkeapää, and Eric Hollinger. 2023. Small Collections Remembered: Sámi Material Culture and Community-Based Digitization at the Smithsonian Institution. *Museum Anthropology* 46(2):92–105. https://doi.org/10.1111/muan.12280.

Miner, Kimberley, Leslie Canavera, Jared Gonet, Kelly Luis, Marisol Maddox, Paul McCarney, Gwen Bridge, David Schimel, and James Rattlingleaf. 2023. The Co-Production of Knowledge for Climate Science. *Nature Climate Change* 13(4):307–308. https://doi.org/10.1038/s41558-023-01633-4.

Mitchell, Dane. 2023. The Point: The Museum of Without. *ArtAsiaPacific* 132. https://search.informit.org/doi/abs/10.3316/informit.926593359669684, accessed February 23, 2024.

Nadasdy, Paul. 1999. The Politics of TEK: Power and the "Integration" of Knowledge. *Arctic Anthropology* 36(1/2):1–18.

Navajo Nation. 2022. Navajo Nation Human Research Review Board (NNHRRB). Electronic document, https://nnhrrb.navajo-nsn.gov/aboutNNHRRB.html, accessed February 23, 2024.

Norström, Albert V., Christopher Cvitanovic, Marie F. Löf, Simon West, Carina Wyborn, Patricia Balvanera, and Angela T. Bednarek. 2020. Principles for Knowledge Co-Production in Sustainability Research. *Nature Sustainability* 3(3):182–190. https://doi.org/10.1038/s41893-019-0448-2.

Oruç, Pinar. 2020. 3D Digitisation of Cultural Heritage: Copyright Implications of the Methods, Purposes and Collaboration. *Journal of Intellectual Property, Information Technology and Electronic Commerce Law* 11(2):149–159. https://www.jipitec.eu/issues/jipitec-11-2-2020/5096.

Oruç, Pinar. 2022. Rethinking Who "Keeps" Heritage: 3D Technology, Repatriation and Copyright. *GRUR International Journal of European and International IP Law* 71(12):1138–1146. https://doi.org/10.1093/grurint/ikac096.

Pagallo, Ugo, and Jacopo Ciani Sciolla. 2023. Anatomy of Web Data Scraping: Ethics, Standards, and the Troubles of the Law. *European Journal of Privacy Law & Technologies* 2023/2:1–19.

Pansoni, S., Simona Tiribelli, Marina Paolanti, Francesco Di Stefano, Emanuele Frontoni, Eva S. Malinverni, and B. Giovanola. 2023. Artificial Intelligence and Cultural Heritage: Design and Assessment of an Ethical Framework. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLVIII-M-2–2023:1149–1155. https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1149-2023.

Pavlidis, George. 2023. From Digital Recording to Advanced AI Applications in Archaeology and Cultural Heritage. In *"And in Length of Days Understanding" (Job 12:12): Essays on Archaeology in the Eastern Mediterranean and Beyond in Honor of Thomas E. Levy*, edited by Erez Ben-Yosef and Ian W. N. Jones, pp. 1627–1656. Springer International, Cham, Switzerland.

Pavlidis, George, Anestis Koutsoudis, Fotis Arnaoutoglou, Vassilios Tsioukas, and Christodoulos Chamzas. 2007. Methods for 3D Digitization of Cultural Heritage. *Journal of Cultural Heritage* 8(1):93–98. https://doi.org/10.1016/j.culher.2006.10.007.

Pedersini, Federico, Augusto Sarti, and Stefano Tubaro. 2000. Automatic Monitoring and 3D Reconstruction Applied to Cultural Heritage. *Journal of Cultural Heritage* 1(3):301–313. https://doi.org/10.1016/S1296-2074(00)01082-7.

People of Kaktovik. 1991. *In This Place: A Guide for Those Who Would Work in The Country of the Kaktovikmiut (Kaktovik Impact Project, 1991)*. Electronic document, https://www.bsee.gov/sites/bsee.gov/files/spill-summary/inspection-and-enforcement/kaktovik-guide.pdf, accessed February 23, 2024.

Pieraccini, Massimiliano, Gabriele Guidi, and Carlo Atzeni. 2001. 3D Digitizing of Cultural Heritage. *Journal of Cultural Heritage* 2(1):63–70. https://doi.org/10.1016/S1296-2074(01)01108-6.

Pittman, Linnea Dale. 2020. Combatting Copyright Overreach: Keeping 3D Representations of Cultural Heritage in the Public Domain. *NYU Law Review*, October 12. https://www.nyulawreview.org/issues/volume-95-number-4/combatting-copyright-overreach-keeping-3d-representations-of-cultural-heritage-in-the-public-domain/, accessed February 23, 2024.

Rainie, Stephanie Carroll, Tahu Kukutai, Maggie Walter, Oscar Luis Figueroa-Rodriguez, Jennifer Walker, and Per Axelsson. 2019. Indigenous Data Sovereignty. In *The State of Open Data: Histories and Horizons*, edited by Tim Davies, Stephen B. Walker, Mor Rubinstein, and Fernando Perini, pp. 300–319. African Minds, Cape Town; International Development Research Center, Ottowa.

Ramachandran, Rahul, Kaylin Bugbee, and Kevin Murphy. 2021. From Open Data to Open Science. *Earth and Space Science* 8(5):e2020EA001562. https://doi.org/10.1029/2020EA001562.

Redman, S., T. Greenhalgh, L. Adedokun, S. Staniszewska, and S. Denegri. 2021. Co-Production of Knowledge: The Future. *British Medical Journal* 372:n434. https://doi.org/10.1136/bmj.n434.

Richards-Rissetto, Heather, and Jennifer von Schwerin. 2017. A Catch 22 of 3D Data Sustainability: Lessons in 3D Archaeological Data Management & Accessibility. *Digital Applications in Archaeology and Cultural Heritage* 6:38–48. https://doi.org/10.1016/j.daach.2017.04.005.

Roued-Cunliffe, Henriette. 2020. *Open Heritage Data: An Introduction to Research, Publishing and Programming with Open Data in the Heritage Sector*. Facet Publishing, London.

Salmond, Amiria. 2012. Digital Subjects, Cultural Objects: Special Issue Introduction. *Journal of Material Culture* 17(3):211–228. https://doi.org/10.1177/1359183512453531.

Sandler, Ronald L. 2014. Introduction: Technology and Ethics. In *Ethics and Emerging Technologies*, edited by Ronald L. Sandler, pp. 1–23. Palgrave Macmillan, London.

Sanger, Matthew C., and Kristen Barnett. 2021. Remote Sensing and Indigenous Communities: Challenges and Opportunities. *Advances in Archaeological Practice* 9(3):194–201. https://doi.org/10.1017/aap.2021.19.

Santana Quintero, M., Sophia Fai, Laurie Smith, Aaron Duer, and Luigi Barazzetti. 2019. Ethical Framework for Heritage Recording Specialists Applying Digital Workflows for Conservation. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-2/W15:1063–1070. https://doi.org/10.5194/isprs-archives-XLII-2-W15-1063-2019.

Scann. 2019. OpenGLAM Principles: Ways Forward to Open Access for Cultural Heritage. *Open GLAM* (blog), April 16. https://medium.com/open-glam/openglam-principles-ways-forward-to-open-access-for-cultural-heritage-81ebb3559b4, accessed February 23, 2024.

Schindling, James, and Cerian Gibbes. 2014. LiDAR as a Tool for Archaeological Research: A Case Study. *Archaeological and Anthropological Sciences* 6(4):411–423. https://doi.org/10.1007/s12520-014-0178-3.

Schmidt, Anne Lisbeth. 2016. The SkinBase Project: Providing 3D Virtual Access to Indigenous Skin Clothing Collections from the Circumpolar Area. *Études Inuit Studies* 40(2):191–205. https://doi.org/10.7202/1055438AR.

Schneider, Flurina, Theresa Tribaldos, Carolina Adler, Reinette (Oonsie) Biggs, Ariane de Bremond, Tobias Buser, Cornelia Krug, et al. 2021. Co-Production of Knowledge and Sustainability Transformations: A Strategic Compass for Global Research Networks. *Current Opinion in Environmental Sustainability* 49:127–142. https://doi.org/10.1016/j.cosust.2021.04.007.

Selden, Robert Z., Timothy K. Perttula, and Michael J. O'Brien. 2014. Advances in Documentation, Digital Curation, Virtual Exhibition, and a Test of 3D Geometric Morphometrics: A Case Study of the Vanderpool Vessels from the Ancestral Caddo Territory. *Advances in Archaeological Practice* 2(2):64–79. https://doi.org/10.7183/2326-3768.2.2.64.

Sequenzia, Gaetano, Gabriele Fatuzzo, and Salvatore Massimo Oliveri. 2021. A Computer-Based Method to Reproduce and Analyse Ancient Series-Produced Moulded Artefacts. *Digital Applications in Archaeology and Cultural Heritage* 20:e00174. https://doi.org/10.1016/j.daach.2021.e00174.

Shein, Esther. 2019. Who Owns 3D Scans of Historic Sites? *Communications of the ACM* 62(1):15–17.

Shotton, Heather J. 2018. Reciprocity and Nation Building in Native Women's Doctoral Education. *American Indian Quarterly* 42(4):488–507. https://doi.org/10.5250/amerindiquar.42.4.0488.

Sketchfab. 2024. Guerrilla-Scanning 3D Models. Electronic document, https://sketchfab.com/tags/guerrilla-scanning, accessed February 23, 2024.

Smith, Linda Tuhiwai. 2021. *Decolonizing Methodologies: Research and Indigenous Peoples*. 3rd ed. Zed Books, London.

Springer Nature. 2024 Open Science and Open Access. Electronic document, https://www.springernature.com/gp/open-science#c26966940, accessed November 23, 2024.

Strathman, Nicole. 2019. Digitizing the Ancestors: Issues in Indigenous Digital Heritage Projects. *International Journal of Communication* 13:3721–3737.

Sumida Huaman, Elizabeth, and Peter Mataira. 2019. Beyond Community Engagement: Centering Research through Indigenous Epistemologies and Peoplehood. *AlterNative* 15(3):281–286. https://doi.org/10.1177/1177180119871705.

Surendran, Nanda K., Xun W. Xu, Oliver Stead, and Heather Silyn-Roberts. 2009. Contemporary Technologies for 3D Digitization of Maori and Pacific Island Artifacts. *International Journal of Imaging Systems and Technology* 19(3): 244–259. https://doi.org/10.1002/ima.20202.

Sylvester, Olivia, Ali García Segura, Sara Ashencaen Crabtree, Zanisah Man, and Jonathan Parker. 2020. Applying an Indigenous Methodology to a North–South, Cross-Cultural Collaboration: Successes and Remaining Challenges. *AlterNative* 16(1):45–54. https://doi.org/10.1177/1177180120903500.

Taiuru, Karaitiana. 2020. *Treaty of Waitangi/Te Tiriti and Māori Ethics Guidelines for AI, Algorithms, Data and IOT*. http://www.taiuru.Maori.nz/TiritiEthicalGuide, accessed February 23, 2024.

Thompson, Erin L. 2017. Legal and Ethical Considerations for Digital Recreations of Cultural Heritage. *Chapman Law Review* 20(1):153–176.

Tsosie, Krystal S., Katrina G. Claw, and Nanibaa' A. Garrison. 2021. Considering "Respect for Sovereignty" beyond the Belmont Report and the Common Rule: Ethical and Legal Implications for American Indian and Alaska Native Peoples. *American Journal of Bioethics* 21(10):27–30. https://doi.org/10.1080/15265161.2021.1968068.

Tuck, Eve. 2009. Suspending Damage: A Letter to Communities. *Harvard Educational Review* 79(3):409–428. https://doi.org/10.17763/haer.79.3.n0016675661t3n15.

Turtle Mountain Band of Chippewa Indians Tribal Council. 2014. *Turtle Mountain Band of Chippewa Indians Research Protection Act*. Electronic document, https://img1.wsimg.com/blobby/go/383bc649-8a6d-4bb4-ad7d-cee900600f66/downloads/TMBCI%20Research%20Protection%20Act.pdf?ver=1702912998790, accessed February 23, 2024.

UNESCO. 2011. What Is Intangible Cultural Heritage? Electronic document, https://ich.unesco.org/en/what-is-intangible-heritage-00003, accessed February 23, 2024.

UNESCO. 2024. Open Research Data—Open Science. Electronic document, https://www.unesco.org/en/open-science/open-research-data, accessed February 23, 2024.

UNESCO Institute for Statistics. 2009. *2009 UNESCO Framework for Cultural Statistics*. Electronic document, https://uis.unesco.org/en/files/unesco-framework-cultural-statistics-2009-en-pdf, accessed February 23, 2024.

US Copyright Office. 2014. Chapter 300: Copyrightable Authorship: What Can Be Registered. *Compendium of US Copyright Office Practices*, 3rd ed. Electronic document, https://law.resource.org/pub/us/compendium/ch300.html, accessed February 23, 2024.

Wachowiak, Melvin J., and Basiliki Vicky Karas. 2009. 3D Scanning and Replication for Museum and Cultural Heritage Applications. *Journal of the American Institute for Conservation* 48(2):141–158. https://doi.org/10.1179/019713609804516992.

Walter, Maggie, and Michele Suina. 2018. Indigenous Data, Indigenous Methodologies and Indigenous Data Sovereignty. *International Journal of Social Research Methodology* 22(3):233–243. https://doi.org/10.1080/13645579.2018.1531228.

Watterson, Alice, and Charlotta Hillerdal. 2020. Nunalleq, Stories from the Village of Our Ancestors: Co-Designing a Multi-Vocal Educational Resource Based on an Archaeological Excavation. *Archaeologies* 16(2):198–227. https://doi.org/10.1007/s11759-020-09399-3.

Wefers, Stefanie, Ashish Karmacharya, Mieke Pfarr-Harfst, and Frank Boochs. 2017. Digital 3D Reconstructed Models: A Proposition for Structuring Visualisation Workflows Using Semantic Technologies for Recommendations. *Studies in Digital Heritage* 1(2):537–546. https://doi.org/10.14434/sdh.v1i2.23327.

Weinberg, Michael. 2016. *3D Scanning: A World without Copyright* *Mostly*. Electronic document, https://michaelweinberg.org/docs/white-paper-3d-scanning-world-without-copyright.pdf, accessed February 23, 2024.

Were, Graeme. 2014. Digital Heritage, Knowledge Networks, and Source Communities: Understanding Digital Objects in a Melanesian Society. *Museum Anthropology* 37(2):133–143. https://doi.org/10.1111/muan.12058.

Wilkinson, Mark D., Michel Dumontier, IJsbrand Jan Aalbersberg, Gabrielle Appleton, Myles Axton, Arie Baak, Niklas Blomberg, et al. 2016. The FAIR Guiding Principles for Scientific Data Management and Stewardship. *Scientific Data* 3: 160018. https://doi.org/10.1038/sdata.2016.18.

Wilson, Shawn. 2008. *Research Is Ceremony: Indigenous Research Methods*. Fernwood Publishing, Black Point, Nova Scotia.

Yilmaz, Hacı Murat, Murat Yakar, Saadet Armağan Güleç, and O. Nuri Dülgerler. 2007. Importance of Digital Close-Range Photogrammetry in Documentation of Cultural Heritage. *Journal of Cultural Heritage* 8(4):428–433. https://doi.org/10.1016/j.culher.2007.07.004.

Yong, Allan, Ali Arya, and Monique Mantch. 2023. Indigenous Technology Empowerment Model: A Community-Based Design Framework. In *2023 IEEE International Conference on Engineering, Technology and Innovation* (*ICE/ITMC*). IEEE, New York. https://doi.org/10.1109/ICE/ITMC58018.2023.10332432.

Younan, Sarah, and Cathy Treadaway. 2015. Digital 3D Models of Heritage Artefacts: Towards a Digital Dream Space. *Digital Applications in Archaeology and Cultural Heritage* 2(4):240–247. https://doi.org/10.1016/j.daach.2015.11.001.

Cite this article: Csoba DeHass, Medeia, Lori Collins, Alexandra Taitt, Julie Raymond-Yakoubian, Travis Doering, Lisa Navraq Ellanna, Eric Hollinger, Jorge Gonzalez, Edwell John Jr., Desireé Martinez, and Meghan Sigvanna Tapqaq. 2025. Ethical Considerations in the Use of 3D Technologies to Preserve and Perpetuate Indigenous Heritage. *American Antiquity*. https://doi.org/10.1017/aaq.2024.82.