Studies in Conservation

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ysic20

Reverse-Engineering History: Re-presenting the Chichester Tablet Using Laser Scanning and 3D Printing

Paul F. Wilson, Mike Donnelly, Ellie King, Mark A. Williams & Alison E. Cooley

STUDIES IN CONSERVATION
https://doi.org/10.1080/00393630.2022.2131204

ORIGINAL RESEARCH OR TREATMENT PAPER

OPEN ACCESS

Check for updates

Reverse-Engineering History: Re-presenting the Chichester Tablet Using Laser Scanning and 3D Printing

Paul F. Wilson [1], Mike Donnelly[1], Ellie King [1], Mark A. Williams [1] and Alison E. Cooley [2]

[1]Centre for Imaging, Metrology and Additive Technologies (CiMAT), Warwick Manufacturing Group, University of Warwick, Coventry, UK; [2]Department of Classics and Ancient History, University of Warwick, Coventry, UK

ABSTRACT

3D digitization methods have become essential tools in cultural heritage practice. Methods like laser scanning and photogrammetry are being widely applied for the conservation of priceless objects and for enabling audience engagement with history. Such data have value as a new wave of multisensory museum practice ripples through the sector and could provide a perfect use for the enormous corpus of 3D data in cultural heritage. This paper documents such an application, where laser scanning has been used in conjunction with 3D printing to re-present the Chichester Roman tablet, an object of key importance in early Romano-British history, to new audiences. It details the process used to digitize the tablet and recreate different versions of its missing text and its state of preservation. It describes how such data can play a role beyond just documentation. Discussed is how such approaches enrich families' engagement in cultural heritage and how such material can used as didactic material in higher education.

ARTICLE HISTORY
Received December 2021
Accepted September 2022

KEYWORDS
3D printing; laser scanning; cultural heritage; Chichester tablet; reverse-engineering; 3D

Introduction

3D digitization methods have radically changed the manner in which cultural heritage objects are used within both academia and public engagement. Non-contact scanning methods have helped to transform the face of cultural heritage, becoming essential tools in the process of discovering, describing, and cataloguing precious historical objects (Pieraccini, Guidi, and Atzeni 2001; Eros and Bornaz 2018). The use of such technology has proliferated rapidly over the past two decades (Wachowiak and Karas 2009; Scopigno et al. 2011; Profico et al. 2019), advertised clearly by the wealth of applications of numerous 3D scanning technologies in the sector, including laser scanning (Yastikli 2007), photogrammetry (Davis et al. 2017), and structured light scanning (Graciano et al. 2017). Other techniques, like reflectance transformation imaging (RTI), are also popular in imaging low-relief objects for documentation and interpretation (Historic England 2018). What our case study demonstrates, however, is the potential for 3D digitization to allow critical engagement with an object, rather than simply to offer a documentation and reflection of it.

The mesh file formats produced by most of these technologies can be easily converted and employed for a wide range of other methods that enable rare and precious objects to be visualized, both for academic study and public consumption. Online model viewers, such as the Smithsonian's 3D database or Sketchfab (Sketchfab 2022), are common in enabling public access. More sophisticated techniques include augmented reality (AR), virtual reality (VR), and 3D printing that present objects to audiences that allow them to explore history through touch or the simple addition of in-context supplementary information within virtual spaces (Jung and Tom Dieck 2017; Wilson et al. 2018). The rapid proliferation of these 3D visualization methods promises to reinvent the ways in which everyone, whether a subject expert, student, or member of the public, engages with cultural heritage.

While research on 3D digitization methods continues to proliferate, what ultimately becomes of this vast quantity of data is much less certain. A vast quantity of research in the area focusses primarily on the data acquisition process, presenting case studies on very specific applications of 3D scanning technologies or focussed exclusively on the processes involved in conservation and/or documentation (Scopigno 2012; Tucci et al. 2017). In many of these publications, authors strongly advocate the potential of utilizing

CONTACT Paul F. Wilson paul.wilson@warwick.ac.uk Centre for Imaging, Metrology and Additive Technologies (CiMAT), Warwick Manufacturing Group, International Manufacturing Centre, University of Warwick, Lord Bhattacharya Way, Coventry CV4 7AL, UK
Supplemental data for this article can be accessed online at https://doi.org/10.1080/00393630.2022.2131204.

3D data for engaging audiences across the sphere of cultural heritage, although these articles rarely detail a concrete example of public use (Laycock et al. 2015; Al-Baghdadi 2017). Less common are case studies of workshops or exhibitions presenting 3D data directly to audiences through media such as AR, VR, or 3D printing (Happa et al. 2009; Dima, Hurcombe, and Wright 2014; Galeazzo 2017; Jung and Tom Dieck 2017). Some authors go so far as to perform evaluations on these applications, though these are few and far between (Nofal et al. 2018; Pollalis et al. 2018). The proportion of 3D data that ends up in use in teaching activities compared to that which remains in data storage is poorly understood at this time. As discussed by Haddad (2012), there is a danger of engaging in dead-end documentation practice, where huge quantities of data are produced that will likely never be looked at again beyond their initial application. There is a need to integrate such data into the whole spectrum of cultural heritage practice, so that the emphasis is not only on documentation but also on utilizing that data for public benefit.

This need arrives at the crest of the multisensory resurgence within cultural heritage practice. The re-emerging desire to engage the senses at cultural heritage sites and museums has come into focus in a similar timeframe, the last two decades showing how multisensory pedagogies are of extreme importance within informal learning settings (Paris 2002; Pye 2008; Chatterjee 2008; Levent and Pascual-Leone 2014). Some museums have already explored the perhaps surprising potential for Latin inscriptions to engage the public via multisensory experiences (Baker and Cooley 2018). Strong evidence supports the use of multisensory interaction with cultural heritage objects in both informal (Davidson, Heald, and Hein 1999; Vi et al. 2017) and formal (Sharp et al. 2015; Kador et al. 2018) educational settings. These typically lean into more learner-centred, constructivist pedagogies which usually result in more satisfying, if less structured, learning experiences. Many authors have discussed the potential of 3D printing (Wilson et al. 2018; Ballarin, Balletti, and Vernier 2018) for helping to fulfil the growing need for multisensory education within cultural heritage, providing a mechanism for producing disposable replicas of precious objects while preserving the original. The growing corpus of 3D digitized data provides a perfect counterpart to the surging interest in multisensory education and, through 3D printing, an outlet for using object data beyond its initial, purely academic, or practical, application.

The Chichester tablet represents an interface between these two waves in cultural heritage. It is a key piece of Romano-British history, even though it preserves only incompletely a Latin text dedicating a temple to Neptune and Minerva under the authority of Tiberius Claudius Cogidubnus, or Togidubnus (Bogaers 1979) (see below, section on conservation of the Chichester tablet) (Figure 1). The incomplete nature of the text lends itself to multiple readings, resulting in uncertainties over how exactly power was brokered between a Celtic ruler and the invading Romans. It is a rare piece of contemporary evidence for the relationship between Britons and Romans in the immediate aftermath of the invasion of Britain by the emperor Claudius in the first century CE, particularly since Britain tends to produce more inscriptions from military than from civilian contexts. The tablet has also had an unusual history since its discovery (as discussed below, section on the Chichester tablet) and is currently installed within the wall of the Town Hall in Chichester, behind a glass frame. The tablet is thus inaccessible to both researchers and the public, the majority of epigraphical work on the tablet using drawings as a reference rather than the original object. The object is also exposed externally and under threat of further degradation over time. The Chichester tablet thus represents a perfect opportunity to reclaim accessibility to the tablet itself, to capture the data not only for the sake of epigraphical practice, but also to enable its use within the sphere of multisensory learning in both museums and higher education through the medium of 3D printing.

In this article, the process of the digitization and replication of the Chichester tablet is detailed in an effort to show how data can be used beyond the

Figure 1. Scanning the Chichester tablet: The tablet is installed under an awning on the left-hand side of Chichester Town Hall. It is normally protected by a glass window, which was removed for the duration of the laser scanning.

mere scope of documentation and research, leveraging the power of multisensory interaction for engaging audiences in both informal and higher education settings.

Research aim

The overall aim of the project is to capture the geometry of the Chichester tablet using laser scanning for several key applications. These are:

- To digitize the Chichester tablet to provide an accessible record for epigraphical research and to document its current condition.
- To determine any traces of missing lettering which could improve the accurate transcription of the text, alongside any other features of interest.
- To reconstruct contrasting interpretations for use in formal and informal educational environments on the difficulties of translating partially complete texts.
- To create physical 3D printed replicas of the original and reconstructed texts for use in public outreach and engagement for Fishbourne Roman Palace and in training students at the University of Warwick in historical methods.
- To assess the extent to which digitization allows a more active learning experience, since the production of two versions of the tablet in a jigsaw puzzle format both invites individuals to recreate for themselves the initial experience of digging up an inscription in fragments and putting it together again, and to engage critically with assessments of different possible readings of the text.

The initial work was carried out in December 2019, when the Chichester tablet was scanned. Processing of the tablet and the reconstruction of the textual interpretations was carried out in the summer of 2020, following delays caused by Covid-19.

Material and methods

The Chichester tablet

In April 1723, workmen uncovered a tablet of Purbeck marble inscribed with a Latin text in the cellar of a house at the junction of North Street and Lion Street near the centre of Chichester (for a summary of the history of the tablet in modern times, see Bogaers 1979, 145–152). Its discovery attracted the attention of the foremost antiquaries of the time, including Roger Gale (Clapinson 2004) and William Stukeley (Haycock 2004), who travelled from London to Chichester in September of the same year to view the inscription where it had been incorporated into a wall of the house where it had been discovered (Gale 1723, 391). In May earlier that year, Edward Bayly, a local rector at Havant, had made a drawing of the inscription, which was then published by Thomas Hearne in 1727 (Vol.1, Appendix to Preface: xxxvii–lvi). Already these two descriptions of the stone and its inscription reveal that reading its text presented challenges. Both Gale (1723, 391–392) and Bayly describe the difficulty of transcribing the inscription confidently, given that it had already suffered some damage especially at line 5. Gale (1723, 391) explains that the tablet had been found face up: consequently, it was damaged by the picks of those seeking to extract it, who inadvertently defaced several letters and broke it into four pieces. The tablet was purchased shortly afterwards from Mr Lodge, proprietor of the house where it was found, by the First Duke of Richmond, who transferred it to Goodwood House (newly acquired in 1720), where it was incorporated into a mock-classical temple constructed upon an artificial mound within the gardens opposite the ‘back front’ of the house (Rouse 1825: vol.1, 342–344 + Plate CXXII). It was flanked by statues of Neptune and Minerva and surmounted by a bust imagined to be of Cogidubnus himself. As a result, it was exposed to weathering outdoors for many years until the Seventh Duke of Richmond presented the tablet to Chichester Corporation in 1907. Since that time, it has been on display, built into the west face of the Town Hall at Chichester. The tablet is currently covered by a wood and glass frame and is mostly protected from the elements under an awning, although is still embedded in an external face of the building (Figure 1).

As Edward Bayly remarked, the tablet’s importance was immediately recognized because of its great antiquity, but that is not the only reason why it has historical significance. The tablet contains information about the dedication of a temple to Neptune and Minerva by a professional association of craftsmen, under the authorization of Ti. Claudius Togidubnus, a name familiar from the pages of Tacitus’ *Life of Agricola*, the biography of his father-in-law Cn. Julius Agricola who served as governor of Britain from CE 77 to 85 (see further on the inscription’s content, section on reinterpreting the Chichester tablet).

Data acquisition

The Chichester tablet was digitized at its current site of preservation. The wood and glass frame was removed for the duration of scanning and the object scanned *in situ* using a Nikon H120 scanner mounted on a MCAx25 + arm with a minimum point resolution of 35 um. The specifications for this machine can be found on the Nikon Metrology project website (Nikon 2021). An industrial-grade, portable, metrological laser scanner was employed to ensure that the best point resolution possible was acquired with the greatest accuracy, to minimize the need for further scanning in the future.

Given the large size of the object (168 × 84 cm) and the limited scanning area of the system, the object was scanned in four separate quadrants. By ensuring each scan included regions of overlapping surface data, the four scan datasets could later be stitched together. The H120 scanner acquires model geometry using its proprietary software, Nikon Focus (Nikon Metrology, England). Data are acquired as points and converted in-software into a triangulated surface mesh file. Multiple passes are made in the area of interest, in each quadrant, to ensure sufficient point acquisition for a more complete surface representation. This entire process of acquisition was around three hours, including equipment set-up and take-down.

The four quadrants were exported as.stl files from Nikon Focus and imported into Geomagic Studio 2014 (3D Systems, United States). They were then registered into alignment using an automated, best-fit alignment that ensured that the individual scans created one, seamless geometry. This was then subjected to the 'Mesh Doctor' utility in Geomagic Studio 2014, which removed 'noisy' geometry such as overlapping triangles and self-intersecting edges due to overlapping surface data. This process ensured a manifold, uniform mesh. This workflow created an extremely high-density mesh with 55.7 million triangles and an unwieldly file size of 2.8 GB. This master mesh was decimated for practicality of mesh processing, resulting in a basic mesh file with 500,000 triangles and a file size of 24.5 MB.

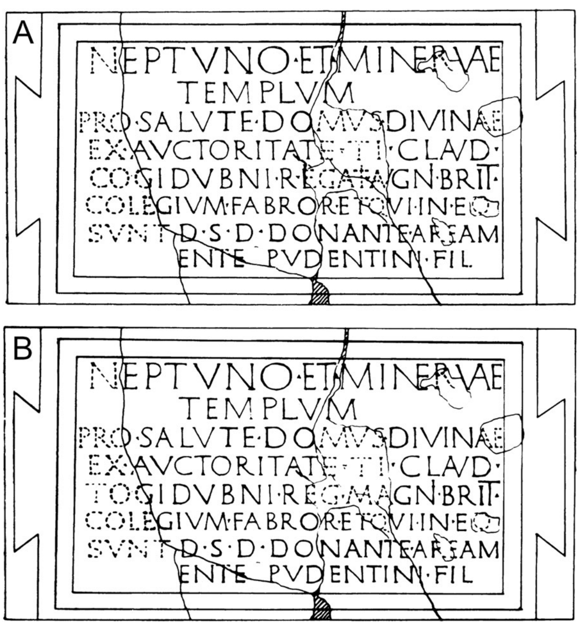

Figure 2. The two interpretations of the Chichester tablet: A = Old Interpretation; B = New Interpretation. Figures taken and edited from Bogaers (1979).

Reconstruction of interpretations

With the tablet digitized, the data was then processed to create three different models for outreach and 3D printing: (1) a default model of its current state of preservation; (2) a model reconstructing the old interpretation of the text (Figure 2(a); see section on reinterpreting the Chichester tablet) and (3) a model reconstructing the new interpretation of the text (Figure 2(b); see section on reinterpreting the Chichester tablet). The former was produced first, with the latter two involving modelling and sculpting of the default model.

The default model was produced by first trimming off any superfluous geometry from the periphery of the initial data mesh, mostly representing incomplete capture of the wooden frame surrounding the tablet. A low-polygon box mesh was then modelled onto the posterior of the data mesh using Geomagic Studio 2014, creating a solid object with closed geometry. This mesh was then cleaned using the Mesh Repair tool in Geomagic Studio 2014, with manual adjustment employed where necessary to avoid over-simplification of geometry. This manual adjustment involved the removal of overlapping faces and superfluous geometry based on the operator's experience. Automated refinement typically results in the loss of potentially informative, original features and deformation of the overall geometry. This produced the default mesh ready for 3D printing (Figure 3).

Following this, two contrasting interpretations of the tablet, 'Old' and 'New', were then created, both using the default model as a base. These differ in how Tiberius Claudius's name is spelt, as 'Cogidubnus' in the 'Old' transcription and 'Togidubnus' in the 'New'. The other major difference regards how the tablet describes his position, as 'king and legate of the emperor in Britain' in the 'Old' translation (a legate being a governor appointed directly by the Roman emperor), or as 'great king of the Britons' in the 'New' transcription (see section on reinterpreting the Chichester tablet). Text was reconstructed using a conservative method, involving the least possible adjustment of the mesh surface to add in the missing

Figure 3. Base mesh of the Chichester tablet: Repaired mesh of the Chichester tablet, rendered in Blender 2.8.

letters for both interpretations. In a few places, missing geometry of existing individual letters was reconstructed to increase legibility, but these changes were minimized to increase authenticity of the interpretation relative to the original model.

Missing letters were spliced into the mesh by duplicating existing pristine letter geometry, moving it into position and scaling so that they matched the height of the other letters in that row. The only letter this was not achievable for was the letter 'X', which was not otherwise present on the tablet. Rather than creating this letter geometry from scratch, a pristine letter 'V' was taken, and the right half of its geometry removed (Figure 4). The remaining left half was then duplicated and then vertically and horizontally mirrored then merged with the original half, to recreate one arm of the 'X'. Finally, this arm was duplicated, horizontally flipped, and merged with the former to create the letter 'X', before being added to the geometry as above. Through this process, both the 'Old' and 'New' textual interpretations were created.

Both the 'Old' and 'New' reconstructions were then separated into jigsaws with each piece being divided roughly along the cracks present on the original (Figure 5(a)). The aim of doing this was to allow students and visitors to gain an appreciation of the challenges faced when the original inscription was first discovered in separate pieces, which then had to be joined together. This jigsaw process involved cutting through the geometry using the Trim tool in Geomagic Studio 2014, filling in the holes around the perimeter to create seven solid, individual pieces. This process was carried out separately on both the 'Old' and 'New' reconstructions, so that the pieces of one could not be mixed with the pieces of the other. These meshes were then cleaned using the Mesh Repair tool in Geomagic Studio 2014, with manual adjustment used to ensure the edges of the pieces were preserved. This process created two sets of seven meshes, the first set representing the 'Old' interpretation and the second set representing the 'New' interpretation (Figure 5(b)).

3D printing

Each of the prepared models was then printed, to be distributed to the various partners associated with the project. A total of five copies of the meshes was created: one of the default mesh, two of the 'Old' interpretation, and two of the 'New' interpretation, were printed on a Stratasys J750 multi-material printer. The parts were printed with a layer thickness of 100 μm in a generic grey colour.

The prints were post-processed following removal of the support material by applying a black wash, a thin paint that fills crevices and creates greater depth and a more authentic finish. Finally, each of the tablets was coated in a matte gloss to protect the finish and provide some protection from future handling. The tablets were then sent to the various partners, one 'Old' and 'New' interpretation to Fishbourne Roman Palace, one default tablet to Chichester Town Council, with one 'Old' and 'New' tablet remaining in the University of Warwick Department of Classics and Ancient History for teaching and outreach purposes, as discussed below (Figure 6).

Reflections on data acquisition process

Overall, the data acquisition process allowed fast and accurate capture of the geometry of the Chichester tablet. This was particularly important given the exposed location of the object and its heavily weathered condition. Acquiring the most accurate possible geometry using a metrological laser-scanner made the most of this limited opportunity, as the work could only be done with the wood and glass frame removed. While the resulting dataset was extremely dense and had an unwieldy file size, this redundancy allowed substantial decimation into a more manageable file size without losing key features of the text or geometry that would occur if a lower resolution scanner was employed. Additionally, the process allows us to further manipulate the data to create numerous interpretations of the text and also provides a secondary data source for the tablet, especially as all academic interpretations of it are based on line drawings, rather than the original tablet. Overall, the process worked well and produced accurate replicas of the tablets for specific outreach and teaching functionalities beyond mere conservation.

Results and discussion

The conservation of the Chichester tablet

The digitization process allowed us to accurately assess the current condition of the Chichester tablet, which has been subjected to much damage since its discovery (Figure 1). Inspection of the default mesh (Figure 3) shows that the left side of the tablet is missing in its entirety and has been restored in fine concrete. The face of this concrete surface is offset from the rest of the tablet by a few millimetres, forming a clear boundary between original tablet and restored concrete. The right-hand side of the tablet has suffered significantly more damage than the remaining central component, with the top-right edge showing severe damage. Also notable is the slightly off-centre right patch of concrete infill that replaces a large chunk of missing lettering, now cracked in places presumably due to subsequent weathering. Aside from other localized 'pockmarks' of damage, the remaining text is well-preserved and legible.

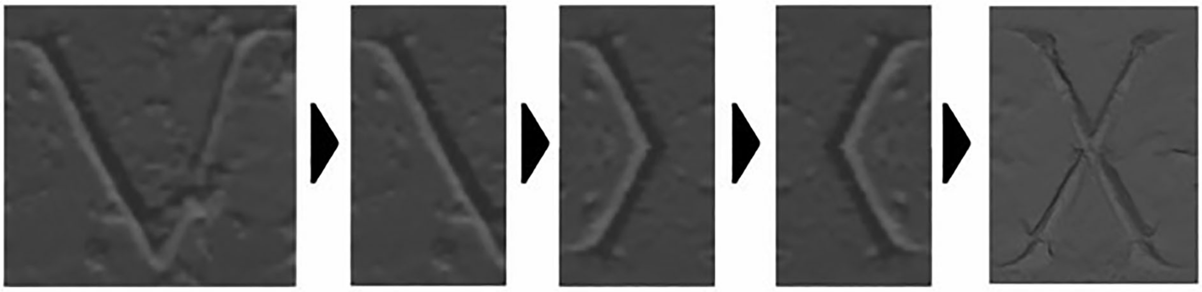

Figure 4. Creation of 'X' letter: As described in the text, the re-creation of the X involved using the geometry of a similar sized V to reverse engineer it, as depicted.

One discrepancy between the tablet and existing interpretations is the final 'E', in the name *Pudentine*, on the eighth line of the tablet (Figure 7(a)). All existing drawn interpretations of the text show this letter as an 'I', which is grammatically correct, identifying the individual as *Pudentini filio,* 'son of Pudentinus'. By contrast, the 'new' photograph in Bogaers (1979: Plate IX) shows an 'E', a mistake that has probably crept in under the influence of the previous word, *[Pud]ente*. It is likely that this is a piece of 'restoration' that took place perhaps during the transfer from Goodwood House to Chichester Town Hall. Its malformed shape might suggest a hasty correction by an unskilled worker, perhaps due to damage caused in transit but naturally this can only be speculation. The fact that some restoration has taken place is also supported by other alterations made to the tablet: some restoration appears to have been extended into the concrete on the missing left-hand portion of the tablet (Figure 7(b)). It is notable that the left arm of the first A on the fourth line has been completed, despite all previous interpretations showing it as incomplete (Bogaers 1979). The same is true of the base of the first G in the sixth line and the back half of the first E of the eighth line. The first O of the third line is seemingly more controversial, a 1921 depiction choosing to complete the O, while subsequent depictions show the modern, incomplete state (Bogaers 1979).

In summary, the Chichester tablet appears to conform with most historical interpretations, with few new insights into the actual transcription being discernible from the scan data. Notable, however, is the presence of a limited amount of restoration to the tablet at some point in its history, likely to have taken place at some point during its installation into Chichester Town Hall in the early twentieth century. This restoration appears to have been fairly light and, in some cases, resulted in typographical errors, as in the case of the extra E in the eighth line. This suggests that any restoration carried out

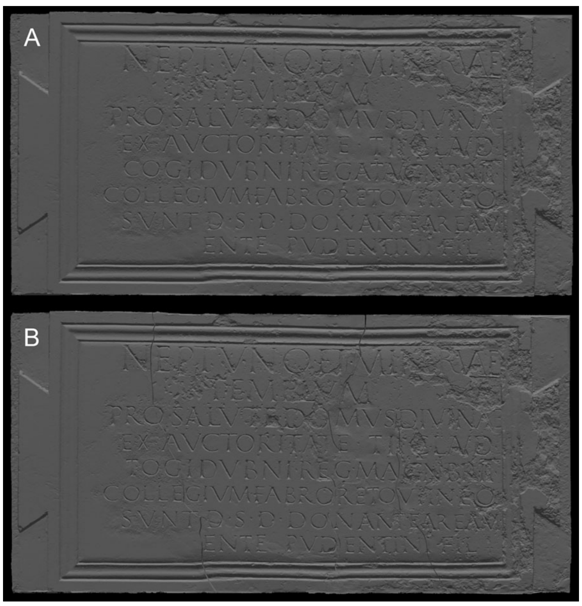

Figure 5. Reconstructed jigsaw meshes of the Chichester tablet: A = Old Interpretation; B = New Interpretation. Rendered in Blender 2.8.

Figure 6. 3D Prints of old and new interpretations: A = Old; B = New. Scale bars equal to 5 mm.

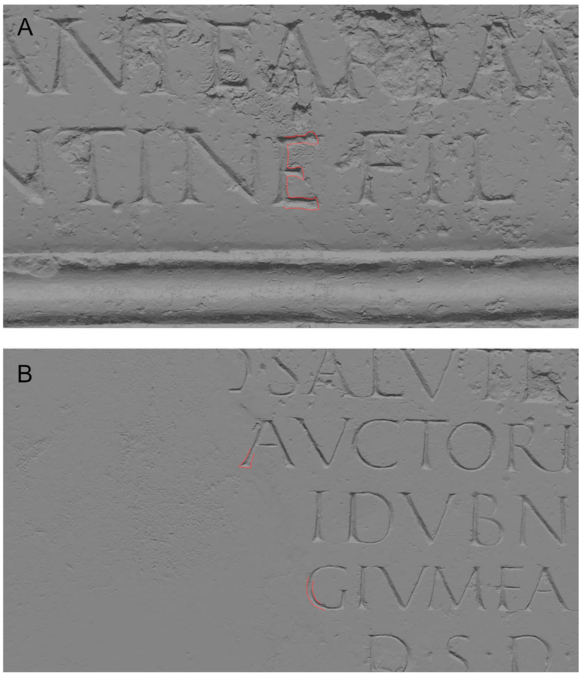

Figure 7. Secondary restoration of lettering on the Chichester tablet: A = Letter 'E' mistakenly restored in modern tablet (zones highlighted in red); B = Restored elements of lettering on repaired area (zones highlighted in red).

may not have been done by an expert, although the reasons as to why and how this was done remain lost to time.

While the scanning process employed was able to accurately capture the condition of the tablet in detail, there were a few shortcomings with regards to the process used. Primarily, it would have been wise to employ complementary scanning methods to both provide more information for experts and for outreach. For example, we could have acquired an image set using a DLSR camera for use in 3D photogrammetry, a favourite in cultural heritage studies (Davis et al. 2017). There is potential opportunity for this in the future but may require some negotiation. This would have provided valuable colour information to assist interpretation and more accurate information on the weathering condition of the tablet, albeit at a lower resolution. Likewise, employing large-scale RTI would have provided another source for interpretation for experts with a manipulatable lighting angle, although a similar output can be created more crudely using the acquired datasets and 3D rendering software, like Blender (Blender Foundation, Netherlands) which is open source. There were also drawbacks of using a metrological scanner, which perhaps was not the best choice for such a large object. This resulted in a very large, if detailed mesh, that proved unwieldly for most mesh processing software and mandated decimation. As discussed above, however, the initial high resolution of the dataset meant that no information was lost during decimation.

Reinterpreting the Chichester tablet

One of the desired outcomes for this project was the potential of discovering any aspects of the geometry of the tablet that might have evaded earlier interpretation and help find a definitive answer as to Tiberius Claudius's true name. This is a small point in the bigger picture, perhaps, but it risks obscuring the real heritage of Celtic Britain as it was incorporated into the Roman Empire.

As outlined earlier (see section on the Chichester table), damage incurred by the tablet hampered the attempts of the first antiquarians who analysed it shortly after its discovery in 1723. The authoritative publication of the tablet in the modern corpus of *Roman Inscriptions of Britain* (Collingwood and Wright 1965: no.91) presents the tablet's inscribed text as follows:

> [N]eptuno et Mineruae / templum / [pr]o salute do [mus] divinae / [ex] auctoritat[e Ti(beri)] Claud(i) / [Co]gidubni r(egis) lega[ti] Aug(usti) in Brit(annia) / [colle]gium fabror(um) et qui in eo / [sun]t d(e) s(uo) d(ederunt) donante aream / [–]ente Pudentini fil(io)

> To Neptune and Minerva, a temple, on behalf of the wellbeing of the divine household, in accordance with the authority of Tiberius Claudius Cogidubnus, king, legate of the emperor in Britain, the association of craftsmen and those who are in it have given at their own expense, [–]ens the son of Pudentinus, donating the area.

This translation depends upon a line drawing produced by one of the editors of the volume, resulting in a subjective (though informed) interpretation of what is on the stone rather than an objective representation. Since the majority of known manuscripts of the *Agricola* mention this individual as Tiberius Claudius Cogidumnus, the inscription was likewise restored for many years as mentioning a Ti(berius) Claudius [C]ogidubnus. Only in 1976, in reviewing the publication of a new edition of the *Agricola*, did Murgia (1977, 339) point out that the name Cogidubnus does not fit into known patterns of Celtic personal names. By contrast, the name Togidubnus would be unexceptional, as derived from Celtic elements togi – 'axe, bow' and dubno – 'deep, underworld' (Russell and Mullen, *CPNRB*, s.v. '[To]gidubnus') and is supported by a single manuscript of the *Agricola,* which preserves the name as Togidumnus, the sounds 'dub' and 'dum' being interchangeable.

Likewise, Tiberius Claudius's relation to the Roman Empire is also under debate. The surface damage to line 5 has two main readings. One (derived essentially from Gale 1723, 393–395, reprinted by Stukeley 1724, 188 and Horsley 1732, 332) interprets the text as referring to Cogidubnus as 'king and legate of the emperor in Britain' (as offered by *RIB*, above) whilst the other proposed by Edward Bayly suggests the reconstruction of 'great king of the Britons'. This is no mere philological debate but reaches into the heart of how an indigenous leader in Britain interacted with the Romans after they invaded and conquered the island under the Emperor Claudius. One thing is clear: Togidubnus was regarded as an ally and friend of Rome, being given Roman citizenship by the emperor himself. Whereas there are many parallels for what have been called 'client kings' or 'friendly kings' elsewhere on the fringes of the Roman Empire, there is no parallel for a king also being a legate. This was a position of delegation from the emperor whereby a leading senator was nominated to serve as his representative in governing a province.

For the reasons set out by Bogaers in 1979, the following reconstruction of the text is likely to be more accurate (differences italicized):

> [N]eptuno et Minervae / templum / [pr]o salute do [mus] divinae / [ex] auctoritat[e Ti(beri)] Claud(i) *[To]gidubni r[eg(is) m]agni Brit(annorum) /* [colle]gium fabror (um) et qui in eo / [sun]ṭ d(e) s(uo) d(ederunt) donante aream / [Pud]ente Pudentini fil(io)

> To Neptune and Minerva, a temple, on behalf of the wellbeing of the divine household, in accordance with the authority of Tiberius Claudius Togidubnus, great king of the Britons, the association of craftsmen and those who are in it gave this temple from their own resources, Pudens, son of Pudentinus, donating the area.

While this interpretation is theoretically more likely, no evidence on the scan data could be found to support either interpretation. No phantom of any letters could be traced, these key few letters being lost to time when the object was excavated. The scan procedure and effort involved was not wasted, however. Here we have been able to provide a detailed account of the current condition of the object, detail the restoration work applied to it over the years and most importantly, leverage the dataset for application beyond the realm of conservation and academic study.

Engaging audiences with 3D printing

As discussed earlier, the true value of 3D digitization lies not only in its ability to document and categorize valuable cultural heritage objects, but in its potential to support education across the spectrum. Through the medium of 3D printing, such data can be given new life in the form of tangible physical replicas for outreach activities, enabling audiences to literally 'get-to-grips' with authentic replicas of their own cultural heritage (Wilson et al. 2018; Warnett et al. 2020). This approach is further finessed in the case of the Chichester tablet, since alternative versions of its text encourage active engagement in evaluating it as a piece of historical evidence.

The field of multisensory interaction in cultural heritage is rapidly growing as practitioners have begun to understand the role of multisensory experiences in generating meaningful, long-term memories (Ward 2014; Wilson et al. 2018). Historical transmission-absorption teaching methods, while effective at provided rigid, scaffolded knowledge, tends to fail in its learning goals in the case of informal learning environments like museums. This is because the exploration of the content of an exhibition gallery is often non-linear, personally mediated, and strongly influenced by the learner's own personal interests and prior knowledge (Hein 1998; Hooper-Greenhill 2007). In museology there is rising focus upon re-introducing the senses back into museum practice, most typically touch, to provide more constructivist learning opportunities and provide support for audiences who may rely less on sight to interact with the world (Ballarin, Balletti, and Vernier 2018; Wilson et al. 2018, 2020). There is strong evidence supporting the benefits of multisensory experiences in informal learning, with participants in such studies often retaining more information and showing greater enjoyment of exhibition content as a result of multisensory interventions, alongside a great desire to see more in museums (Davidson, Heald, and Hein 1999; Vi et al. 2017; Eardley et al. 2018). The use of 3D prints for such experiences has received much less research attention but appears to show that such models can support informal learning experiences and are at least desired by audiences (Turner et al. 2017; Wilson et al. 2018; Nofal et al. 2018).

In higher education, the use of multisensory teaching experiences has also received some positive attention. Object-based learning (OBL), a teaching approach championed by University College London (UCL), has been successfully employed in teaching undergraduate classes in material culture (Chatterjee 2010; Duhs 2010). A number of studies show that allowing students to engage with physical artefacts can help understanding and support learning in students. Sharp et al. (2015) carried out a study evaluating OBL lessons at UCL across biosciences, earth science and humanities disciplines, finding that students who engaged in these classes showed higher graded scores, although this effect was more prominent in those who had not taken such practical classes before. Similarly, Hardie (2015) carried out an evaluation of an OBL-based class in graphic design, finding that the majority of students liked the 'hands-on' nature of the class, but some found that it did not mesh well with their learning styles. Other authors provide more anecdotal evidence for positive support in the use of OBL in higher education, which is generally positive (Tam 2015; Kador et al. 2018). Through the medium of 3D printing, it is possible to use stored scan data to create accurate replicas to support teaching in higher education. Getting replicas of unique, priceless objects into the hands of students provides an excellent opportunity to inspire interest in their interpretation of material culture and most importantly, train the next wave of practitioners in interpreting key historical objects, rather than only permitting engagement with teaching collections.

The 3D prints are intended for exactly this purpose, to teach students about the technical discipline of epigraphy – its value and its pitfalls. Although traditionally inscriptions tend to be incorporated into historical teaching as texts printed in a book, our 3D printed models will allow an innovative opportunity for students to grasp the idea of inscriptions not just as 'documents' but as 'monuments' too, an approach advocated by recent scholarship (Cooley 2012, section II.3.a, 'Monuments, not documents'). In this way, students will actively gain a deeper understanding of the social and cultural contexts within which such inscriptions were originally produced. Copies of the 'Old' and 'New' tablets are to be embedded in a brand-new module for first year undergraduates, 'Encounters with Material Culture: Objects and Archaeology', which will run for the first time in spring 2023. The Chichester Tablet replicas will offer an interactive way to engage students in thinking about how ancient material culture contributes to our reconstruction of ancient history, becoming aware of the need to view even published material with healthy scepticism. Our choice of interactive 3-D jigsaw puzzle enables such an approach, which would not be possible through other imaging techniques such as RTI. The module will provide an excellent case study for the use of 3D printed replicas in higher education. Studies on engagement with regards to student's learning outcomes and opinions is the subject of future research following the work of Di Franco et al. (2015, 2016) and other scholars (Sharp et al. 2015; Tam 2015).

A copy of the 'Old' and 'New' texts in their jigsaw format have been donated to Fishbourne Roman Palace, where they have been used to engage visitors in the history of the area, as revealed by the Chichester tablet. The palace has run an event that used these prints to engage with the history of C/Togidubnus and early Romano-British history in a more constructivist, multisensory manner. While they have no plans to carry out a formal evaluation of the prints and how their audience interacted with them, they provided us with general feedback on how their audiences responded to the jigsaw puzzles. On 6 August 2021, Fishbourne Roman Palace held an event with 1,237 attendees at which visitors were able to interact with the puzzles. The organizers found that children were more focussed on the ludic play of assembling the pieces of the jigsaws rather than the epigraphical content, but while they did so adults generally engaged volunteers to find out more about the inscription, using the worksheets provided for this use (see Supplemental Appendix). It is difficult to assess learning impact from the generic information provided, but it seems like the tablets were used as intended and provided a good, interactive talking point for visitors to engage with their own cultural heritage. The staff at Fishbourne Roman Palace also had some concern about the size of some of the pieces, which were approximately sized to the non-concrete chunks for authenticity. In future, it might provide better usability to make the pieces more arbitrary shapes with greater size and robustness, to alleviate such concerns.

The files will also be uploaded onto Sketchfab under the control of Fishbourne Roman Palace, in order to provide researchers and the public with access to a more direct source to the text, rather than the line drawings which currently only provide a subjective, less detailed modality of reading and interpreting the text.

The possibility of creating an interactive way of learning about the past is fundamental to this project, offering the opportunity to re-experience what it may have been like to try to make sense of an inscription which was in fragments when it was dug out of its cellar. This will, we hope, encourage people to develop a critical and informed approach to historical heritage, which goes well beyond being informed about the past to an approach that allows everyone to have fun in evaluating the sources upon which our historical narratives are now based.

Conclusions

In all, cultural heritage institutions have a responsibility to make use of their collections beyond the simple act of digitization. Rather, the true value in conservation is the use of such data in teaching, both for the next generation of students of material culture and for the public, as tangible windows into history. We have shown the importance of this through the Chichester tablet, a key Romano- British artefact whose interpretation changes the way in which the initial conquest is viewed by history. Through 3D printing, such material can be leveraged to support education in both informal and formal settings and increase the societal value of cultural practice.

Acknowledgements

The authors are grateful to the support of Mr Peter Roberts, Chichester City Council, and Dr Robert Symmons, Curator at Fishbourne Roman Palace. Special thanks goes to Dr Kathryn van de Wiel, who sparked the initial interest in the project.

Disclosure statement

No potential conflict of interest was reported by the author (s).

Funding

This research was funded by the Institute for Advanced Study (IAS) Awards Scheme, University of Warwick.

ORCID

Paul F. Wilson http://orcid.org/0000-0002-7243-4372
Ellie King http://orcid.org/0000-0001-9573-1874
Mark A. Williams http://orcid.org/0000-0003-3802-7914
Alison E. Cooley http://orcid.org/0000-0003-4324-7241

References

Al-Baghdadi, M. A. R. S. 2017. "3D Printing and 3D Scanning of Our Ancient History: Preservation and Protection of Our Cultural Heritage and Identity." *International Journal of Energy and Environment* 8: 441–456.

Baker, A., and A. Cooley. 2018. "Breaking Through the Language Barrier – Bringing "Dead" Languages to Life Through Sensory and Narrative Engagement." *Museum Management and Curatorship* 35: 428–446. doi:10.1080/09647775.2018.1501601.

Ballarin, M., C. Balletti, and P. Vernier. 2018. "Replicas in Cultural Heritage: 3D Printing and the Museum Experience." In *ISPRS TC II Mid-Term Symposium "Towards Photogrammetry 2020", Volume XLII-2*, edited by F. Remondino, I. Toschi, and T. Fuse, 55–62. Hannover: ISPRS.

Bogaers, J. E. 1979. "King Cogidubnus in Chichester: Another Reading of "RIB" 91." *Britannia* 10: 243–254.

Chatterjee, H. J. 2008. *Touch in Museums: Policy and Practice in Object Handling*. Oxford: Berg.

Chatterjee, H. J. 2010. "Object-Based Learning in Higher Education: The Pedagogical Power of Museums." *University Museums and Collections Journal* 3: 179–181.

Clapinson, M. 2004. "Gale, Roger (1672–1744), Antiquary." *Oxford Dictionary of National Biography*. Accessed 16 May 2021. https://0-www-oxforddnb-com.pugwash.lib.warwick.ac.uk/view/10.1093ref:odnb/9780198614128.001.0001/odnb-9780198614128-e-10294.

Collingwood, R. G., and R. P. Wright. 1965. *The Roman Inscriptions of Britain I: Inscriptions on Stone*. Oxford: Clarendon Press.

Cooley, A. E. 2012. *The Cambridge Manual of Latin Epigraphy*. Cambridge: Cambridge University Press.

Davidson, B., C. L. Heald, and G. E. Hein. 1999. "Increased Exhibit Accessibility Through Multisensory Interaction"." In *The Educational Role of the Museums*, edited by E. Hooper-Greenhill, 223–238. London: Routledge.

Davis, A., D. Belton, P. Helmholz, P. Bourke, and J. McDonald. 2017. "Pilbara Rock Art: Laser Scanning, Photogrammetry and 3D Photographic Reconstruction as Heritage Management Tools." *Heritage Science* 5: 25. doi:10.1186/s40494-017-0140-7.

Di Franco, P. D. G., C. Camporesi, F. Galeazzi, and M. Kallmann. 2015. "3D Printing and Immersive Visualization for Improved Perception of Ancient Artifacts." *Presence* 24: 243–264.

Di Franco, P. D. G., J. L. Matthews, and T. Matlock. 2016. "Framing the Past: How Virtual Experience Affects Bodily Description of Artefacts." *Journal of Cultural Heritage* 17: 179–187.

Dima, M., L. Hurcombe, and M. Wright. 2014. "Touching the Past: Haptic Augmented Reality for Museum Artefacts." In *Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality. VAMR 2014. Lecture Notes in Computer Science*, edited by R. Shumaker, and S. Lackey, 3–14. Cham: Springer.

Duhs, R. 2010. "Learning from university museums and collections in higher education: University College London (UCL)." *University Museums and Collections Journal* 3. doi:10.18452/8698

Eardley, A. F., C. Dobbin, J. Neves, and P. Ride. 2018. "Hands-On, Shoes-Off: Multisensory Tools Enhance Family Engagement Within an Art Museum." *Visitor Studies* 21: 79–97.

Eros, A., and L. Bornaz. 2018. "3D Models in Cultural Heritage: Approaches for Their Creation and Use." *International Journal of Computational Methods in Heritage Science* 1: 1–9. doi:10.4018/IJCMHS.2017010101.

Gale, R. 1723. "An Account of a Roman Inscription Found at Chichester." *Philosophical Transactions* 32: 391–400.

Galeazzo, L. 2017. "Mapping Change and Motion in the Lagoon: The Island of San Secondo." In *Visualizing Venice: Mapping and Modelling Time and Change in a City*, edited by K. L. Huffman, and A. Giordano, 43–50. Oxford: Routledge.

Graciano, A., L. Ortega, R. J. Segura, and F. R. Feito. 2017. "Digitization of Religious Artifacts with a Structured Light Scanner." *Virtual Archaeology Review* 8: 49–55. doi:10.4995/var.2016.4650.

Haddad, N. A. 2012. "Educational Multimedia Entertainment (EME) and Childhood Heritage Awareness". *Proceedings of the 1st International Conference on Best Practices in World Heritage: Archaeology*. Menorca, Spain, 9–13th April.

Happa, J., M. Williams, G. Turley, G. Earl, P. Dubla, G. Beale, G. Gibbons, K. Bedattista, and A. Chalmers. 2009. "Virtual Relighting of a Roman Statue Head from Herculaneum: A Case Study." In *AFRIGRAPH"09: Proceedings of the 6th International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa*, edited by S. N. Spencer, 5–12. New York: Association for Computing Machinery.

Hardie, K. 2015. "Engaging Learners Through Engaging Designs That Enrich and Energise Learning and Teaching." In *Engaging the Senses: Object Based-Learning in Higher Education*, edited by H. J. Chatterjee, and L. Hannan, 21–42. Surrey: Ashgate Publishing.

Haycock, D. 2004. "Stukeley, William (1687–1765), Antiquary and Natural Philosopher." *Oxford Dictionary of National Biography*. Accessed 10 December 2021. https://0-www-oxforddnb-com.pugwash.lib.warwick.ac.uk/view/10.1093ref:odnb/9780198614128.001.0001/odnb-9780198614128-e-26743.

Hearne, T. 1727. *Adami de Domerham. Historia de Rebus Gestis Glastoniensibus 2 Vols*. Oxford: Sheldonian Theatre.

Hein, G. E. 1998. *Learning in the Museum*. London: Routledge.

Historic England. 2018. "Multi-Light Imaging: Highlight-Reflectance Transformation Imaging (H-RTI) for Cultural Heritage". *Historic England*. Accessed 20 August 2021. https://historicengland.org.uk/images-books/publications/multi-light-imaging-heritage-applications/.

Hooper-Greenhill, E. 2007. *Museums and Education*. Oxford: Routledge.

Horsely, J. 1732. *Britannia Romana*. London: John Osborn and Thomas Longman.

Jung, T. H., and M. C. Tom Dieck. 2017. “Augmented Reality Virtual Reality and 3D Printing for the Co-Creation of Value for the Visitor Experience at Cultural Heritage Places.” *Journal of Place Management and Development* 10: 140–151.

Kador, T., L. Hannan, J. Nyhan, M. Terras, H. J. Chatterjee, and M. Carnall. 2018. “Object-Based Learning and Research-Based Education: Case Studies from the UCL Curricula.” In *Teaching and Learningin Higher Education Perspectives from UCL*, edited by J. P. Davies, and N. Pachler, 157–206. London: UCL Institute of Education Press.

Laycock, S. D., G. D. Bell, N. Corps, D. B. Mortimore, G. Cox, S. May, and I. Finkel. 2015. “Using a Combination of Micro-Computed Tomography, CAD and 3D Printing Techniques to Reconstruct Incomplete 19th Century Cantonese Chess Pieces.” *ACM Journal on Computing and Cultural Heritage* 5: 13.

Levent, N., and A. Pascual-Leone. 2014. *The Multisensory Museums: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory and Space*. Plymouth: Rowman and Littlefield.

Murgia, C. E. 1977. “The Minor Works of Tacitus: A Study in Textual Criticism.” *Classical Philology* 72 (4): 323–343.

Nikon. 2021. MCAx S. Accessed 5 May 2022. https://industry.nikon.com/en-gb/products/3d-laser-scanners/manual-3d-scanning/mcaxs/.

Nofal, E., R. M. Reffat, V. Boschloos, H. Hameeuw, and A. V. Moere. 2018. “The Role of Tangible Interaction to Communicate Tacit Knowledge of Built Heritage.” *Heritage* 1: 414–436.

Paris, S. G. 2002. *Perspectives on Object-Centered Learning in Museums*. London: Lawrence Erlbaum Associates.

Pieraccini, M., G. Guidi, and C. Atzeni. 2001. “3D Digitizing of Cultural Heritage.” *Journal of Cultural Heritage* 2: 63–70.

Pollalis, C., E. J. Minor, L. Westendorf, W. Fahnbulleh, I. Virgilio, A. L. Kun, and O. Shaer. 2018. “Evaluating Learning with Tangible and Virtual Representations of Archaeological Artifacts.” In *TEI”18 Proceedings of the 12th International Conference on Tangible, Embedded, and Embodied Interaction*, edited by Y. Fernaeus, D. McMillan, M. Jonsson, A. Girouard, and J. Tholander, 626–637. New York: ACM.

Profico, A., L. Bellucci, C. Buzi, F. Di Vincenzo, I. Micarelli, and F. Strani. 2019. “Virtual Anthropology and its Application in Cultural Heritage Studies.” *Studies in Conservation* 64: 323–336.

Pye, E. 2008. *The Power of Touch: Handling Objects in Museums and Heritage Contexts*. Walnut Creek: Left Coast Press.

Rouse, J. 1825. *Beauties and Antiquities of the County of Sussex, 2 Vols*. London: J. F. Setchel.

Russell, P., and A. Mullen. *Celtic Personal Names of Roman Britain (CPNRB)*. Accessed 16 May 2021. www.asnc.cam.ac.uk/personalnames/details.php?name=27.

Scopigno, R. 2012. “Sampled 3D Models for Cultural Heritage: Which Uses Beyond Visualization?” *Virtual Archaeology Review* 3: 109–115.

Scopigno, R., M. Callieri, P. Cignoni, M. Corsini, M. Dellepiane, F. Ponchio, and G. Ranzuglia. 2011. “3D Models for Cultural Heritage: Beyond Plain Visualization.” *Computer* 44: 48–55.

Sharp, A., L. Thomson, H. J. Chatterjee, and L. Hannan. 2015. “The Value of Object-Based Learning Within and Between Higher Education Disciplines.” In *Engaging the Senses: Object-Based Learning in Higher Education*, edited by H. J. Chatterjee, and L. Hannan, 97–116. Surrey: Ashgate Publishing.

Sketchfab. 2022. “*Sketchfab*”. Accessed 10 October 2022. https://sketchfab.com/.

Stukely, W. M. 1724. *Itinerarium curiosum*. London: Leigh and Sotherby.

Tam, C. O. 2015. “Three Cases of Using Object-Based Learning with University Students: A Comparison of Their Rationales, Impact and Effectiveness.” In *Engaging the Senses: Object-Based Learning in Higher Education*, edited by H. J. Chatterjee, and L. Hannan, 117–132. Surrey: Ashgate Publishing.

Tucci, G., B. Bonora, A. Conti, and F. Fiorini. 2017. “High-Quality 3D Models and Their Use in Cultural Heritage Conservation Project.” *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII: W5.

Turner, H., G. Resch, D. Soutwick, R. McEven, A. K. Dube, and I. Record. 2017. “Using 3D Printing to Enhance Understanding and Engagement with Young Audiences: Lessons from Workshops in a Museums.” *Curator: The Museum Journal* 60: 311–333.

Vi, C. T., D. Ablart, E. Gatti, C. Valasco, and M. Obrist. 2017. “Not Just Seeing, But Also Feeling Art: Mid-Air Haptic Experiences Integrated in a Multisensory Art Exhibition.” *International Journal of Human-Computer Studies* 108: 1–14.

Wachowiak, M. J., and B. V. Karas. 2009. “3D Scanning and Replication for Museum and Culturage Heritage Applications.” *Journal of the American Institute for Conservation* 48: 141–158.

Ward, J. 2014. “Multisensory Memories: How Richer Experiences Facilitate Remembering.” In *The Multisensory Museum: Cross-Disciplinary Perspectives on Touch, Sound, Smell, Memory and Space*, edited by N. Levent, and A. Pascual-Leone, 273–284. Plymouth: Rowman and Littlefield.

Warnett, J. M., M. A. Williams, P. F. Wilson, and M. P. Smith. 2020. “The Oxford Dodo. Seeing More Than Ever Before: X-Ray Micro-CT Scanning, Specimen Acquisition and Provenance.” *Historical Biology* 32. doi:10.1080/08912963.2020.1782396.

Wilson, P. F., S. Griffiths, E. Williams, M. P. Smith, and M. A. Williams. 2020. “Designing 3D Prints for Blind and Partially Sighted Audiences in Museums: Exploring the Needs of Those Living with Sight Loss.” *Visitor Studies*. doi:10.1080/10645578.2020.1776562.

Wilson, P. F., J. Stott, J. M. Warnett, A. Attridge, M. P. Smith, and M. A. Williams. 2018. “Evaluation of Tangible 3D-Printed Replicas in Museums.” *Curator: The Museum Journal* 60: 445–465.

Yastikli, N. 2007. “Documentation of Cultural Heritage Using Digital Photogrammetry and Laser Scanning.” *Journal of Cultural Heritage* 8: 423–427.