

Impact case study (REF3)

Institution: Loughborough University		
Unit of Assessment: D32 Art and Design: History, Practice and Theory		
Title of case study: Enabling Museums to Improve Visitor Experience through Innovative Digital Design Techniques		
Period when the underpinning research was undertaken: 2009 to 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof Ian Campbell	Reader, Professor	2000 to present
Prof Richard Bibb	Reader, professor	2008 to present
Dr Ian Graham	Researcher, Lecturer	2006 to present
Dr Abby Paterson	Lecturer	2014 to present
Dr Fangjin Zhang	Researcher	2014 to 2015
Period when the claimed impact occurred: 2014 to 2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact		
<p>Museums need innovative ways to improve visitor experience while protecting cultural heritage. Research at Loughborough University developed new approaches for 3D scanning and 3D printing of cultural artefacts and provided a new methodological approach for artefact restoration and replication. Cultural heritage partners (including Forbidden City, Beijing; Manchester Museum; Kelvingrove Museum, Glasgow; World Museum, Liverpool; Museum of Wigan Life) used this knowledge during major replication and restoration projects, with the following impacts: 1) Two economic benefits – a) established a new artefact restoration and replication company with £290k annual turnover, and b) reduced the cost and time needed for artefact restoration at four organisations; and 2) increased public engagement and improved visitor experience at two major exhibitions.</p>		
2. Underpinning research		
<p>Early museums provided a sensory experience where visitors could hold and interact with displayed objects. In the nineteenth century, a shift towards conservation concerns contributed to the move away from physical interaction. Recent decades have seen a shift back towards interactive exhibits, requiring museums to manage the difficult balance between protecting artefacts and improving visitor experience. Push-button displays provide a degree of hands-on interaction but with increasing technology available within homes (e.g., games consoles) the novelty of this experience is becoming limited. Museums need to fully exploit the benefits of innovative digital design technologies to improve the preservation, exhibition, and replication of rare, valuable, and fragile artefacts.</p> <p>This research programme, conducted by Campbell, Bibb, Graham and Paterson, aimed to determine how 3D scanning and 3D printing technologies could be used to maximum benefit in the heritage sector. The research identified the different combinations of techniques most appropriate to individual artefacts to assist in their replication or restoration, requiring consideration of accuracy, timescales, and costs. This was achieved through research projects examining how artefacts with a wide range of materials, sizes and required accuracy should be processed. The research also applied these digital tools to visualisation and representation of human anatomy in the medical field [R1].</p>		

The research involved 3D scanning and physical reproduction of cultural artefacts. Eleven projects involved Chinese partners: six projects with the Director of Restoration, Palace Museum (2009 – 2019); two projects with the Director of Research, Summer Palace Museum (2012 – 2015 & 2019 - present); two projects with the Director of Management, Garden Museum (2013 – 2015); one project with the Director of Exhibition Design, Palace Museum (2018 - present). The accuracy, cost and timing data generated through these projects was used to develop a new methodological approach for accurate and efficient replication and restoration of artefacts [R2], [R3]. The twelfth project involved collaboration with archaeologists at the University of Manchester (2014 – 2020), Prof Andrew Chamberlain, Professor of Bioarchaeology, and Dr Lidija McKnight, Research Fellow, Dept of Earth and Environmental Sciences. The 3D printing and scanning research at Loughborough focused on developing techniques for the visualisation and physical reproduction of anatomy and artefacts from within mummified animals. This involved the isolation of bone anatomy data to facilitate definitive species identification. Computer-aided visualisation techniques were developed to help visitors better understand the contents of mummies. Physical items were produced to enable handling and physical interpretation by museum staff and visitors, with special attention paid to visually impaired visitors [R4], [R5].

Overall, the research generated new knowledge on how to better 3D scan ancient, mummified objects and manipulate 3D scan data in preparation for 3D printing, optimising the effectiveness of 3D scanning and 3D printing in mummified animal species identification, and developing a new methodological approach for artefact restoration and replication.

3. References to the research

- R1:** Bibb R, Eggbeer D, Paterson A, "Medical modelling: the application of advanced design and development technologies in medicine", 2nd edition, Elsevier (Woodhead), Cambridge, UK, January 2015, ISBN 978-1-78242-300-3. *(supplied by HEI on request)*
- R2:** Zhang, F, Campbell, RI, Graham, IJ, "Application of Additive Manufacturing to the Digital Restoration of Archaeological Artefacts", International Journal of Rapid Manufacturing, 2017, 6(1), pp.75-94, ISSN: 1757-8825. <https://doi.org/10.1504/IJRAPIDM.2016.078747>.
- R3:** Zhang, F, "Digital applications in the field of heritage preservation", in Beijing papers on the history of garden culture, p365-372, Edited by Society of the Summer Palace, China Social Press, Beijing, 2013 *(supplied by HEI on request)*
- R4:** McKnight LM, Adams JE, Chamberlain A, Atherton-Woolham SD, Bibb R, "Application of clinical imaging and 3D printing to the identification of anomalies in an ancient Egyptian animal mummy", Journal of Archaeological Science: Reports, 2015, 3: pp.328–332, <https://doi.org/10.1016/j.jasrep.2015.06.028>
- R5:** McKnight L and Bibb R, "4.6 Industrial imaging" in McKnight L and Atherton-Woolham S (eds) Gifts from the Gods: Ancient Egyptian Animal Mummies and the British, Liverpool University Press, 2015, UK, ISBN: 978-1-78138-255-4, pp 82-85 *(supplied by HEI on request)*

The research was published in peer reviewed journals and books. It was funded by a competitively awarded HEIF grant from Loughborough's Enterprise Projects Group.

4. Details of the impact

Close collaboration with many of the museums was embedded within the underpinning research, creating an immediate pathway for the two key impacts:

Impact 1: New economic activity in cultural heritage restoration and replication.

a) New artefact restoration and replication company established in China.

A new private company was established in China in 2014 to provide the expertise generated through our research to museums and other organisations, on a commercial basis. Nanjing

Shuwei Cultural Creative Co. Ltd. has one full-time employee and had a 2019 turnover of approximately £290k [S1].

b) The cost and speed of artefact restoration and replication was reduced while artefact quality was improved at three museums in China and the UK and at a theme park in China. The techniques discovered in our research [R2, R3] have been adopted by leading museums in China (in collaboration with Nanjing Shuwei Cultural Creative Co. Ltd) and the UK. The Palace Museum in Beijing (aka the Forbidden City) is the most visited museum in the world, with approximately 19 million visitors in 2019. In 2019, 3D-printed replicas of an ancient vase and plant were displayed in a special exhibition. 3D-printed cloisonné replicas were displayed in the Forbidden City when the Qianlong Garden opened to the public in 2020. The Director of Restoration, Ancient Architecture Department, Palace Museum, stated:

“The partnership ... has enabled the Palace Museum to achieve many more of its restoration targets than would otherwise have been possible. It is estimated the overall time saving over a five-year period has been in the region of 1,800 hours” [S2].

Full-size replicas of the two guardian lions from the entrance to the Summer Palace are now displayed at the entrance to the new Garden Museum in Beijing (see Figure 1). The techniques used to produce the bronze and marble replicas outperformed conventional processes, which had failed to replicate the undercuts on fine detailed relief sculpture.



Figure 1: Replica guardian lion at the entrance to the Garden Museum (left) and the original lion at the entrance to the Summer Palace (right).

In the UK, 3D scanning of hidden artefacts wrapped within Egyptian animal mummies was completed for the Manchester Museum. The data was used to produce 3D-printed replicas of the previously unseen artefacts. The Curator of Egypt and Sudan at the Manchester Museum states:

“... the use of 3D prints in these contexts have been really transformative... in testing assumptions of what mummies actually contain...” [S3].

The replication techniques were also used in non-museum organisations, e.g., consultancy work for the Aero-Sun Engineering Art Co. towards building a 76m tall statue of a Chinese empress. This is a central attraction in the Huayi Brothers’ movie theme park in Suzhou, near Shanghai. The theme park attracts around 5 million visitors per year [S].

Impact 2: Increased public engagement with, and improved visitor experience at two major exhibitions.

Our research led to an improvement in the quality of museum exhibitions by using 3D scan data to create virtual reality (VR) presentations and 3D-printed replicas [R2, R3, R4, R5].

At a major exhibition in the Forbidden City, visitors were able to engage in immersive VR experiences and touch the 3D-printed replica artefacts. Writing about this exhibition, the Director of Design in the Exhibition Department of the Palace Museum stated:

“the partnership ... has enabled the Palace Museum to explore new means of introducing digital technology into exhibition spaces” [S5].

Another major exhibition, “Gifts for the Gods: Animal Mummies Revealed”, was initially held at Manchester Museum in 2015 and subsequently at the Kelvingrove Museum in Glasgow, the World Museum in Liverpool, and the Museum of Wigan Life. At least 300,000 individual visitors saw the original and touring exhibition in person, with over 165,000 people using Manchester’s related social media resource. 3D printing proved successful in demonstrating to visitors the previously hidden artefacts inside the linen wrappings of the animal mummies. Visitor feedback was captured at the first three venues, which showed increased visitor engagement due to the use of science and technology in the study of cultural artefacts. For example, visitors stated:

“A fascinating exhibition, amazing to see the mummified creatures.”

“It was brilliant to be able to touch the replica artefacts and fascinating to learn about the technology that enabled them to be produced” [S6].

As part of the Gifts for the Gods exhibition tour, a range of targeted engagement events were held for the public, including evening ‘Mummy Re-rollings’, daytime talks, guided tours, and sessions for school visitors (covering educational Key Stages 1 to 4). These evolved over time to include handling sessions using the 3D replicas (see Figure 2, below).



Figure 2: Digital visualisations of mummy and hidden artefacts (left) and handling session using 3D-printed replicas (right).

5. Sources to corroborate the impact.

S1: Company registration certificate (Chinese Mandarin, with translation)

S2: Testimonial letter from the Director of Restoration, Ancient Architecture Department, Palace Museum.

S3: Testimonial letter from the Curator of Egypt and Sudan at the Manchester Museum.

S4: Testimonial letter from the Director of Nanjing Aerosun Art Engineering.

S5: Testimonial letter from the Director of Design, Exhibition Department, Palace Museum.

S6: Evaluation of Gifts for the Gods touring exhibition conducted by volunteer guide.