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Digital Modalities in Knowledge Co-Production: Mapping a Culture Shift in GLAM Institutions

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ANN BORDA
MUKI HAKLAY
KIRSTY WALLIS
LUCY ROBINSON
VICTORIA IVANOVA
TIM CAUSER
TIM LEONARD
SUSANNE HECKER
ELISABETH HEYNE
ULRIKE STURM
SHARON RUSTON

*Author affiliations can be found in the back matter of this article

ABSTRACT

The GLAM (galleries, libraries, archives, and museums) sector has long been associated with forms of participatory innovation supported by digital modalities. Within GLAMs, crowdsourcing has been a particularly visible form of citizen science in the collection and analysis of large datasets and contribution to scholarly research, often addressing complex challenges and focusing on public value. However, we have limited understanding of the roles and practices of GLAMs in fostering deeper forms of community participation using digital modalities, such as in knowledge co-production, and the attributes of a culture shift that might support, promote, empower, and sustain these approaches.

In this qualitative study, these considerations are explored through six case studies across representative GLAM institutions, and through collective reflections on responsive modes of participation in line with diversifying digital modalities of knowledge co-production and potential identifiers of culture shift. Our study outcome suggested that the strongest shift in GLAMs relates to making participatory approaches, mediated by digital modalities, part of mainstream activities through institutional strategies and project missions. A modest shift yet, although the case studies further highlight the potential for knowledge co-production to serve translational purposes in the community, supported by digitally enabled modalities of participation to help scale, reinforce, re-shape, and strengthen this process, and not least challenge traditional boundaries of knowledge co-production.

CORRESPONDING AUTHOR:
Ann Borda
University College London, United Kingdom; The University of Melbourne, Australia
aborda@unimelb.edu.au

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INTRODUCTION

Facilitating connections between people, cultures and communities is an essential capacity in, and an inherent strength of galleries, libraries, archives, and museums (GLAMs) (Avdikos et al. 2024). This can involve participating in and contributing to how we can foster and strengthen civil society in terms of personal responsibility, altruistic service, and environmental stewardship, for instance (Borda and Bowen 2025). These precepts are readily aligned to citizen science, here understood as the umbrella term encompassing a range of activities from crowdsourcing to participatory action research (Haklay et al. 2021). In the past two decades, citizen science as a practice has steadily moved from marginal areas of academia to a more visible and prominent place within the practices of scholarly enquiry and research (Hecker et al. 2018; Hetland, Pierroux, and Esborg 2020; Strasser et al. 2023).

Within GLAMs, crowdsourcing has been a particularly visible form of citizen science (Holley 2010; Owens 2013; Ridge 2013; Hedges and Dunn 2017; Bonacchi et al. 2019). Collecting and analysing large datasets has been at the root of many such citizen science projects for decades and is a well-established practice in disciplines across ecology, astronomy, biodiversity, archaeology, medicine and health, among others (Vohland et al. 2021). Online crowdsourcing in cultural heritage has grown alongside these trends, spurred on by "Web 2.0" (the two-directional Web), which shifted websites towards allowing for greater user participation, collaboration, and interaction (Capriotti et al. 2016). Shortly after Web 2.0 heralded in a new era in the early 2000s, crowdsourcing examples, such as the steve.museum tagging project (2006–2008), Flickr Commons image-sharing site (launched 2008), and the National Library of Australia's newspaper transcription and text correction project on its *Trove* platform (launched 2008), flourished in GLAM sectors (Hedges and Dunn 2017; Bonacchi et al. 2019). The availability of the open project builder on Zooniverse.org from 2015 and the US Library of Congress *By the People* collections transcription initiative in 2018, represented a second wave of crowdsourcing.

While forms of crowdsourcing can be considered to be collaboration "at a distance" between researchers and project participants (Bonacchi et al. 2019), and even extractive (Owens 2013; Riley and Mason-Wilkes 2023), in the context of this paper, we are defining crowdsourcing in GLAMs as "a form of digitally-enabled participation that promises deeper, more engaged relationships with the public via meaningful tasks with cultural heritage collections" (Ridge, Ferriter, and Blickhan et al. 2021, p. 2). Within this boundary of deeper, meaningful engagement, citizen science is increasingly being identified as a multi-stakeholder process, aimed at a democratisation of policy, open participation, and open innovation (Göbel et al. 2019; Godinho et al. 2021; Dressen 2025; Lamberti, Lopez-Sintas and Katz-Gerro 2025). For example, crowdsourced citizen science is a critical way in which collective governance is manifested by bringing together researchers, civil society, and GLAM stakeholders to address complex challenges, most often using solutions-oriented and participatory approaches focusing on public good (Herzog and Lepenies 2022; Strasser et al. 2023).

The GLAM sector has also long been associated with adopting social innovation, making GLAM institutions more relevant and impactful (Simon 2010; Desmarchelier, Djellal, and Gallouj 2025). Participatory innovation in GLAM communities is evolving and being enabled by a range of digital modalities (Ridge 2013; Giglitto et al. 2019; Gooch, Kahn, and Kugeler 2025) across Internet platforms, browser-based and mobile applications (Bowen et al. 2023), Virtual Reality (Hollister 2024), and artificial intelligence (AI) applications (Bonacchi et al. 2019; Ceccaroni et al. 2023).

Yet with clear and growing evidence for public willingness and enthusiasm to participate (Hetland, Pierroux, and Esborg 2020; Borda and Bowen 2025), there is a noticeable gap in our understanding of the roles and practices of GLAMs in fostering "deeper" (e.g., two-way) and sustained forms of community participation using digitally enabled and multimodal interactions (Bowen et al. 2023), particularly in knowledge co-production processes (Graham 2016; Black 2018; Ridge, Ferriter, and Blickhan et al. 2021). Here, "knowledge co-production" refers to a set of iterative processes bringing together diverse groups and their ways of knowing to co-produce new knowledge or knowledge-based solutions for public good outcomes (Ligtermoet et al. 2025).

This qualitative study aims to explore what potential culture shift might be necessary for GLAMs to beneficially support and sustain these approaches (Black 2018; Eleta et al. 2019), as well as more responsive modes of activation in line with diversifying digital modalities of knowledge co-production (Huang and Liem 2022). The study identifies these considerations through case studies across representative GLAM institutions, and through collective reflections to build a discourse to inform potential pathways for future collaboration around shared insights and practices.

METHODOLOGY

For this study, we carried out an iterative search of representative literature, and a case study approach in line with a research investigation of a phenomenon within a real-world context.

	ORGANISATION	CASE STUDY	REFERENCES
1	Museum für Naturkunde (Berlin, Germany) Muséum national d'Histoire naturelle (Paris, France)	*Changing Natures (CN)*	Sturm et al. 2022 Heyne et al. 2024
2	University College London (London, UK)	*Transcribe Bentham (TB)*	Causer and Terras 2014
3	Natural History Museum (London, UK)	*National Education Nature Park (NENP)*	Burton et al. 2024
4	University College London (London, UK)	*UCL citizen science support service (UCSS)*	Wallis 2022
5	Lancaster University (Lancaster, UK)	*Davy Notebooks Project (DNP)*	Ruston et al. 2024
6	Serpentine Galleries (London, UK)	*Future Art Ecosystems (FAE)*	Ivanova and Ding 2025

Table 1 Participating GLAM organisations and case study projects.

Qualitative case study approaches informed the design of this study (Merriam 1998; Bartlett and Vavrus 2017) and can be characterised as focusing on a particular phenomenon (e.g., situation, event, program), describing the phenomenon, and applying heuristics (Merriam 1998).

The lead researchers applied purposive sampling (Ahmad and Wilkins 2025) to identify GLAM representatives appropriate for the study scope who are specifically and institutionally involved in citizen science projects supported by co-production using digitally enabled platforms. The selection process was not intended to cast a wide net of diverse participants, but to invite individuals known to the lead researchers whose insights could provide depth and richness to the discourse, for example, across different digital modalities of participation (e.g., content creation, data analysis, data collection, tagging, transcription), duration of project (two or more years), and representative types of GLAM organisations (e.g., gallery, library, archive, museum). We also made the distinction between structured knowledge co-production guided by a research problem or knowledge gap or shared "goal" (Holley 2010), with that of public engagement with collections, the latter of which can be transitory or a one-way interaction (Holley 2010; Graham 2016). Central to the study was alignment with the criteria of structured knowledge co-production in participatory contexts that have an emphasis on digitally enabled two-way and multimodal interactions. We aimed for a maximum of six case studies, also taking into consideration that more than one GLAM representative might be associated with a given case study and would be open to participate.

Six projects are represented herein as case studies, each hosted or led by a GLAM organisation (Table 1).

GLAM PARTICIPATION

The GLAM representatives who accepted the invitation are associated with or directly involved in the oversight or operation of projects/programmes falling within the study remit. GLAM representatives collaborated as co-authors in this study, contributing relevant case study descriptions using publicly available information. They were further supported by published research and resources from the projects or institutions with which they are involved (Table 1).

Owing to the heterogeneity of the case studies, the collaborators agreed on a template with primary field categories (Crabtree and Miller 1999) and supporting open text prompts to describe their cases so that consistency in format and primary content could be maintained (Table 2). In most cases, the resulting information was more recent and thematically descriptive than published research (see Supplemental File 1: Appendix).

A subsequent deductive thematic analysis of the case studies was carried out following Braun and Clarke (2022).

THEMATIC CATEGORY	PROMPTS
Project / Programme	• Type of GLAM organisation • Unit/department for project/ programme • Project description • Website/URL • References
Mission	• Organisation • Project alignment with citizen science
Participation	• Descriptive (e.g., numbers, type) • Engagement scope
Digital modalities	• Use by public • Internal to team
Knowledge co-production	• Modes • Output(s) • Producers/partners
Skills/expertise	• Public engagement • Other
Funding and Sustainability	• Project/programme • Scope • Sustainability
Culture shift	• Organisational • Author reflection(s) • Author role in organisation

Table 2 Case study template.

The thematic analysis relied upon the reflexivity (Berger 2015) of the author-participants, who were able to draw on their case study and use it to address their experiences and especially to identify potential evidence of culture shifts in knowledge co-production in GLAM contexts (See the section "Reflections on mapping a culture shift").

CASE STUDY SUMMARIES

A summary description of each of the six case study projects is outlined below, drawn from the project template across the following categories: Institution(s), Description, Project Mission, Participation, Digital Modalities, Knowledge Co-production, Project URL/Screenshot. The full case study data corresponding to the Table 2 categories are provided in Supplemental File 1: Appendix.

ANALYSIS OF CASE STUDIES

The analysis (Fereday and Muir-Cochrane 2006) was conducted by assigning primary themes drawn from the template (Table 2) and subcategories drawn from the prompts as the basis for grouping horizontal findings and for high-level analysis across the studies (See Table 3).

CASE STUDY: CHANGING NATURES (CN) **https://www.changing-natures.org/**
Institution(s): Museum für Naturkunde (MfN), Berlin and Muséum national d'Histoire naturelle (MNHN), Paris
Description: The project addresses anthropogenic environmental change by inviting citizens to contribute directly to the creation of a digital collection. Project duration: 2020–present.
Project mission: The project focuses on individual perspectives on human-made environmental transformations: What things from the past can tell us stories about these changes? Which objects and memories surprise us today? What have we long forgotten—or never noticed?
Participants: Pupils, retired adults, academic and non-academic, those living in France, Germany, and European Countries
Digital modalities: • Multilingual online collection platform enabling object upload, metadata tagging, and commenting • A folksonomy system allowing users to generate and expand keyword categories • Online collection exploration through a gallery view, object-centered views and map • Interactive game *Ecocene* using AI-generated imagery
Knowledge co-production: Participants co-produce knowledge through: • object selection for the collection; • adding metadata and comments to objects; and • platform co-design through focus groups.

CASE STUDY: TRANSCRIBE BENTHAM (TB) **https://www.ucl.ac.uk/transcribe-bentham**
Institution(s): University College London (UCL) Special Collections; UCL Educational Media. Repository managed by UCL Library, Culture, Collections and Open Science (LCCOS). Content partner: The British Library.
Description: The project focuses on the crowdsourced transcription of the papers of Jeremy Bentham, philosopher and reformer (1748–1832) using an online citizen science platform supported by UCL Advanced Research Computing. Project duration: 2010–present
Project mission: The aim of the Bentham Project (founded 1959) is to produce the new authoritative edition of *The Collected Works of Jeremy Bentham*, and to act as the global centre for the study of Bentham's life and work.
Participants: c. 500 in total, but the majority of contributions are from 43 "Super Transcribers," i.e. volunteers contributing high-quality work on a regular basis.
Digital modalities: Volunteers engage in the following ways: • Transcribe and encode manuscripts through the "Transcription Desk," a customised MediaWiki • Add TEI-XML tags (Text Encoding Initiative is a de facto international standard for encoding machine-readable texts using Extensible Markup Language) • Contribute to online knowledge exchanges
Knowledge co-production: • Collaborative production and revision of transcripts of original Bentham manuscripts • Project staff use volunteer transcripts in scholarly editing of volumes of *The Collected Works of Jeremy Bentham*, with volunteers credited in the preface to volumes • Transcripts are uploaded, alongside the manuscript image, to UCL Library's digital Bentham Papers repository • Volunteers have helped co-develop the transcription platform

CASE STUDY: NATIONAL EDUCATION NATURE PARK (NENP) **www.educationnaturepark.org.uk**

Institution(s): The Natural History Museum London, with Royal Horticultural Society, Learning Through Landscapes, Royal Society, UK Centre for Ecology and Hydrology, National Biodiversity Network Trust, Manchester Metropolitan University, Royal Geographical Society, Esri UK

Description: The project aims to achieve and study biodiversity gains and nature recovery on school, college and nursery sites across England, alongside embedding nature and climate in the curriculum, developing young people's green skills, pro-environmental behaviours and enhancing wellbeing.
Project duration: 2022–present. Coverage: England-wide

Project mission:
The NENP has five goals:

1. to increase biodiversity across the education estate;
2. to develop green and digital skills;
3. to improve young people's wellbeing;
4. to promote pro-environmental behaviours; and
5. to involve every young person in formal education in England.

Participants:
More than 9,000 schools, colleges, and nurseries in England registered for the programme as of March 2026, representing over 30% of primary and secondary schools in England. Of these, more than 40% have participated in community science research activities in the first 2.5 years.

Digital modalities:

- Website and social media
- Geographic information system (GIS) browser-based tools
- iNaturalist app for species observations
- Access to data via a GIS-based digital map, enabling community scientists to visualise and analyse their own and others' data

Knowledge co-production:

- Young people (with support of educators)
  - map habitats on their online learning site and conduct nature surveys to record biodiversity;
  - develop a vision for their site and interventions; and
  - visualise data on a map and annotate and use it to inform their decisions and track their progress towards nature recovery.
- Educators
  - download data for curriculum teaching and use data to inform climate action plans.
- Youth Science Forum
  - young people collaborate with project postdoctoral researchers.

CASE STUDY: UCL CITIZEN SCIENCE SUPPORT SERVICE (UCSS) **https://www.ucl.ac.uk/library/open-science-research-support/open-science/citizen-science**

Lead: University College London (UCL) Office of Open Science and Scholarship (OOSS), partnered with Citizen Science Academy, UCL Institute of Global Prosperity, Co-Production Collective and ExCiteS Research.

Description:
The UCSS service enables connections between existing projects and facilitates a growing community doing citizen science across disciplines. It also supports the Citizen Science Academy, offering citizen science education and training support embedded within active research projects and imparting knowledge and practical skills enabling place-based social action across different modalities. The service is a first within a UK University Research Library.
Duration: 2020–present

Participants:
Communities in local, national, and international projects undertaking crowdsourcing, humanities, local history, public health, and volunteer and community computing projects, among others.
More than 100 students and academic staff members are part of the community.

Digital modalities:

- Digital platforms and open-source tools
- Online UCSS community network for UCL staff and students to connect, share knowledge and experiences, and spark creativity in participatory research

Knowledge co-production:

- UCSS supports and enables knowledge co-production across UCL-led and partner projects, for example:
  - open science approaches to participatory research; and
  - resources co-produced with project teams.

CASE STUDY: DAVY NOTEBOOKS PROJECT (DNP) **https://wp.lancs.ac.uk/davynotebooks**

Lead: Lancaster University, with Adler Planetarium in Chicago, University College London, and University of Manchester.

Description: The project focuses on the crowdsourced transcription of the notebooks of Sir Humphry Davy, chemist and inventor (1778–1829), using the Zooniverse platform.
Project duration: 2019–2024

Project mission:
The aims of the DNP were to:
- digitise and make publicly available the full collection of Sir Humphry Davy's notebooks held at the Royal Institution of Great Britain in London and Kresen Kernow in Redruth, Cornwall;
- engage volunteers in crowdsourced transcription of the notebooks; and
- change public views of the relationship between art and science.

Participants:
Volunteers geographically dispersed around the world with a range of academic/non-academic backgrounds.
More than 4,300 volunteers transcribed and classified the notebooks, and added annotations on scientific terms, people, places, and events.

Digital modalities:
- Zooniverse platform for crowdsourced transcription and collaboration
- Discussion threads on Davy Notebooks Talk Forum

Knowledge co-production:
- Volunteer transcription of notebooks led to discoveries of terms "sodarchium," "potarchium," "potagen," and "sodagen," early names for two new elements Davy isolated: sodium and potassium.
- Volunteers helped to develop new understandings of places that Davy visited, thought, and wrote about, and his personal and professional networks.

CASE STUDY: FUTURE ART ECOSYSTEMS (FAE) **https://futureartecosystems.org/**

Lead: Serpentine Galleries, London, UK. Collaboration with artists Holly Herndon and Mat Dryhurst on the choral AI exhibition titled *The Call*, with partnerships including community choral groups across the UK, Centre for Data Futures, King's College London, RadicalxChange, AWO and Keystone Law.

Description: FAE is a program that developed the first trusted data intermediary within a cultural organisation to enable responsible data stewardship for AI training.
The case study references the crowdsourced exhibition "The Call" (2024–25), which is positioned within the FAE framework and Choral Data Trust Experiment. The central aspect of *The Call* is its choral AI models, trained in collaboration with choirs in the UK. To train the AI model, the artists composed a set of hymns and singing exercises and recorded them being sung by 15 choirs. "The Call" also approaches the idea of a data trust in which the choristers or creators who want to want to train AI with their data have a say in its usage. The Trust is a type of data intermediary established as a body with representation from the choirs, artists, and Serpentine that can create and formalise data agreements and serve as an ongoing decision-making and stewardship body for future data governance.
Project duration: 2020–present (FAE) | Choral Data Trust Experiment established: 2024

Participants: 15 UK community choirs (300 choristers, 120 soloists), artists Holly Herndon and Mat Dryhurst, FAE team members and partners.

Digital modalities:
- Recorded choral performances
- Compositions and recordings optimised for a choral AI dataset and training choral AI models

Knowledge co-production:
- Participant co-production outcomes comprise:
  - high-quality performance recordings (483);
  - choral AI dataset for training choral AI models;
  - Data Trust Experiment, resulting in a responsible data stewardship model; and
  - Practical roadmap for "trusted data intermediaries."

A deductive thematic analysis was guided by recurring thematic clusters arising in the data collected for each of the studies (see Supplementary File 1: Appendix. Data Tables S1–S8). Primary groupings and subcategories were derived from these data tables and outlined in Table 3, with analysis following in this section. Note that case studies are referred to by project initials in the analysis and subsequent discursive sections: Changing Natures (CN), Transcribe Bentham (TB), National Education Nature Park (NENP), UCL Citizen Science support service (UCSS), Davy Notebooks Project (DNP), and Future Art Ecosystems (FAE).

DIVERSE CHARACTERISTICS

The six case studies are hosted or led by different GLAM types: two originating with museums, three hosted by library and academic departments at a university, and one led by a public art institution. The six GLAM organisations have a form of charitable status, and one organisation (Natural History Museum London) is a national arms-length government body. Of the six case studies, four institutions are based in London, England, one in a regional county of England (Lancaster), and one in Europe (Berlin, Germany and Paris, France). They all, however, represent participatory coverage beyond their institutionally situated geographies.

The selected case studies represent diverse approaches to knowledge co-production and use of digital modalities in support of this. Although the sample size is small, the case studies have particular characteristics to support insights within the overarching study, such as the purpose-built transcription platform in the decades-long crowdsourced GLAM project, TB (2010–present); the open crowdsourced platform, Zooniverse, which supports DNP (2019–2024); and the trusted data intermediary experiment of the FAE project, comprising crowdsourced choral data for AI model training (2024–present) (see Figure 1). The case studies also uniquely support knowledge co-production across different platforms and modalities, such as the hybrid NENP (2022–present) initiative of the National History Museum; the two geographic nodes of online participation and co-production across object collections in the CN project (2020–present) (see Figure 2); and the UCSS (2020–present) position as an enabler in capacity-building in knowledge co-production across open science approaches and citizen science leadership.

PRIMARY THEME	SUB-CATEGORIES
Organisation	GLAM type
	Mission/purpose
	Geographic location
Project	Mission/purpose
	Subject focus
	Geographic coverage
	Duration
Participation	Participation type(s)
	Participants
	Recruitment
	Scale (numbers)
Digital modalities	Tools
	Data
Knowledge co-production	Enablers
	Challenges
Funding and sustainability	Funding
	Sustainability
	Organisational commitment

Table 3 Thematic analysis by primary theme and subcategories.

The thematic focus of individual projects varies across the studies, encompassing the papers of historical figures (TB and DNP), environmental change (CN), environmental stewardship (NENP), choral music (FAE), and open and community science (UCSS). Differences further relate to project participation scales. Some case studies, for example, represent large numbers of participants (> 1,000) and broad geographic scope, whereas others are considerably smaller in terms of numbers (< 100) but large in terms of volume of contributions. For example, the NENP represents a large geographic coverage of the whole of England, with 9,000 schools and tens of thousands of participants, whereas TB has had fewer than 100 regular participants

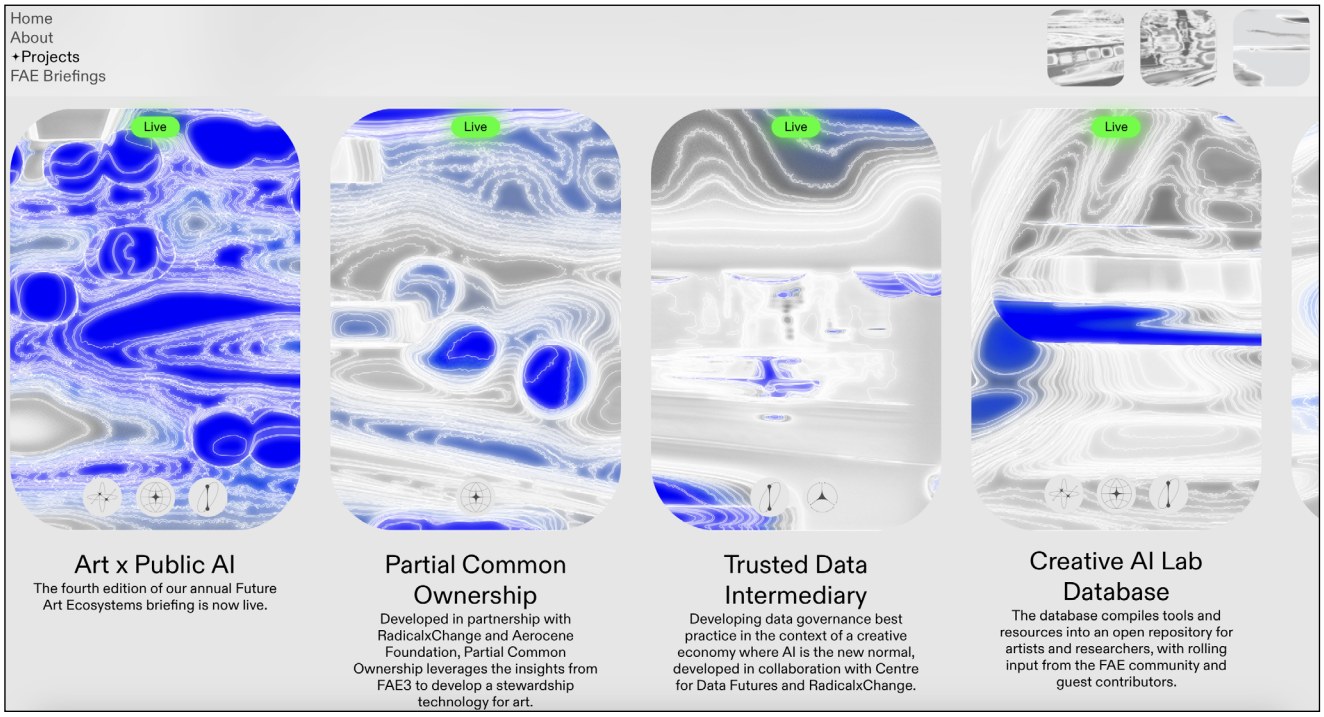


Figure 1 Projects page of *Future Art Ecosystems* showing the "Trusted Data Intermediary" project link. https://futureartecosystems.org/projects/.

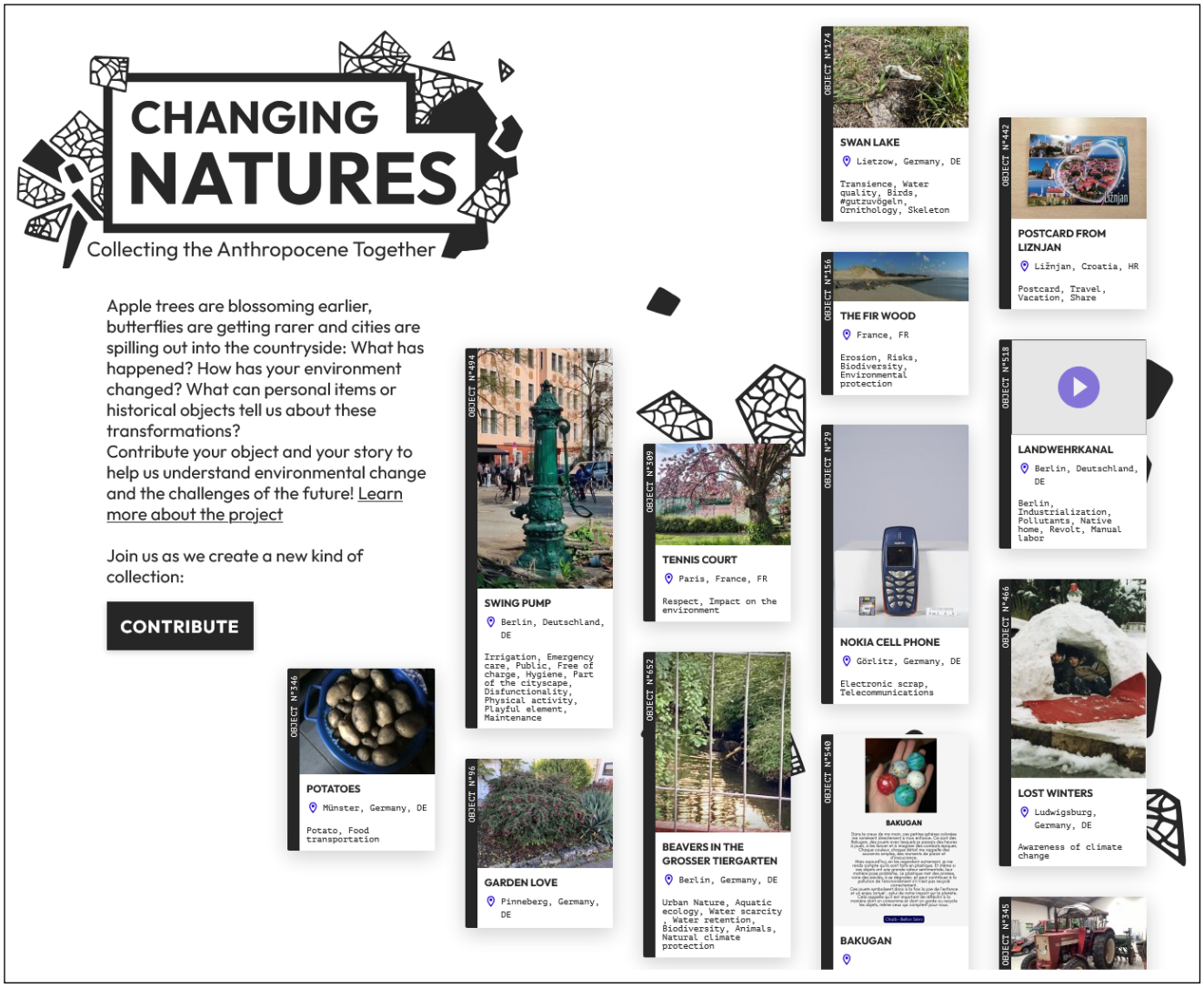


Figure 2 Changing Natures project home page, showing online public contributions (English language version), https://www.changing-natures.org/en/.

(internationally distributed), they have contributed the majority of the 44,000 transcribed manuscript pages.

Participants engaged in the projects come from across the complete spectrum of society, from children, teachers, and schools to open calls of local people and wider international public, through to communities of academic staff, media artists, and choral groups. In this way, digital modalities can similarly differ in the scale to which they support diversity in participation, for example, collecting data, analysing data, contributing to metadata, sharing data, or generating new data. Data tasks are supported in a variety of ways across crowdsourcing platforms (TB and DNP), AI data model development (FAE), mixed modalities of web-based engagement (CN), and GIS and mobile apps (NENP). Online platforms include well-established tools like the iNaturalist app (NENP) and Zooniverse platform (DNP), but also custom-developed software like wikis and transcription tools (TB). In some cases, participatory platforms were custom-built to integrate scientific and cultural metadata, including unconventional data categories such as "emotion," as in the CN project.

SHARED CHARACTERISTICS

The six case studies shared some institutional characteristics: Project missions drew up agendas for the public good, such as putting citizen science and participatory practices at the core of organisations; interactions around collections and collection practices were re-thought; and they contributed to scholarly research. The organisational missions have synergistic cross-overs, such as "community science" as a priority theme reflected in the Natural History Museum's "Museum Strategy to 2031", while the UCSS fulfils a mandate based on the report by League of European Research Universities (LERU) (Wyler and Haklay 2018) to serve as a central point of knowledge-sharing about citizen science—the latter underlining that GLAM institutions can

go beyond implementation of participatory projects to sustaining a citizen science ecosystem.

Mission statements of each of the case studies highlight the centrality of collaborative involvement in knowledge co-production activities. These are enabled through community support mechanisms, such as focus groups (e.g., CN and FAE) and dedicated community science services (e.g., UCSS). Not least, there is a dedicated web presence of projects, wikis, and blogs, and support for publicly accessible resources, for example, the CN online project page has a dynamic front page showing examples of public contributions with available English language version (Figure 2) and the FAE page provides open resources linked to its portfolio of projects, such as the "trusted data intermediary" project (Figure 1).

There is also the embedding of participation across the research lifecycle from research problem–setting to results dissemination, as in the FAE, UCSS, and CN projects. Two-way modalities in knowledge co-production were similarly reinforced by the case studies, supporting forms of reciprocal value (Kelty et al. 2015), such as knowledge exchanges (all six studies), shared scholarship (TB and DNP), skills (UCSS and NENP), and agency (CN, FAE, and NENP). For instance, TB transcription volunteers are credited in prefaces to volumes of the Collected Works of Jeremy Bentham, DNP transcribers have assisted in uncovering new insights (Ruston et al. 2024), and FAE participants have collaboratively shaped a public data collective governance framework and legal rights collectivisation, of which they are rights-holders (Ivanova and Ding 2025). This is further augmented in the GLAM sector with the launch of OpenGLAM Principles in 2011 (https://openglam.org/principles/), and the Declaration on Open Access for Cultural Heritage in 2020–21.

All six case studies promote some form of open access, open source, and open data—a critical underpinning of digital modality processes and co-production in the GLAM citizen science community for a number of years (Bonacchi et al. 2019; Dressen 2025). The use of Media Wiki for TB is an example of an open shareable tool that was developed for a cultural project and available for other text and transcription tasks. The DNP transcription project was built on the open-source Zooniverse platform and the completed digital collection hosted on a Lancaster instance of the Cambridge Digital Collections platform. Not least, the directive towards collaborative two-way digital modalities are features of open science adoption (Hecker et al. 2018), operationalised in CN, NENP, and UCSS.

CHALLENGES IDENTIFIED

Identifying challenges across the different case studies point to acknowledged gaps in our understanding of emerging and dynamic forms of knowledge co-production using diverse digital modalities. For example, outputs can inadvertently be interculturally or semantically insensitive or misinformed about local contexts of lived experience, and/or highlight issues of asymmetric governance and agency (Eleta et al. 2019; Göbel et al. 2019; Mihelj, Leguina, and Downey 2019). In addressing agency, the FAE has revolved around the operationalisation of collective data governance, for instance, and new mechanisms for data stewardship extending beyond the opt-in and opt-out from AI datasets.

Related issues of participation concern volunteer management such as recruitment, retention, and reciprocity. The example given by TB notes that despite enormous amounts of work completed since 2010, the bulk of transcriptions (over 90%) has been done by 43 "super-transcribers." This crowdsourcing conundrum raises the fact that volunteers can exhibit a pattern of participation inequality (Strasser et al. 2023; Jönsson et al. 2024; Poetz and Sauermann 2024). There is often a need to reach out to a very large group of participants, characterised as "broadcast searching," (Poetz and Sauermann 2024) in order to engage and retain a small proportion of highly committed volunteers (Causer and Terras 2014). The extent, or lack of, participation diversity is a particular challenge (Pateman and West 2023). A body of evidence shows how volunteer motivations in citizen science are complex and highly dynamic, differing between participants and within participants over time (Spiers et al. 2019; Strasser et al. 2023). The reciprocity of participation can be lessened in data-centred relationships, which can be extractive (Riley and Mason-Wilkes 2023), so by engaging and respecting participants' expertise and local knowledge through multimodal forms of interaction and trust, the case studies have endeavoured to support meaningful participation (Kelty et al. 2015).

How to participate effectively is a question related to digital literacy; it is a challenge underpinned by the same skills that support the establishment of online community platforms and their resources (Giglitto et al. 2019). There is arguably a concurrent gap in participation due to lack of access to digital infrastructures and inequalities of representation and discoverability, for example, how content and its creators are made visible across digital platforms (Mihelj, Leguina, and Downey 2019). A couple of the studies advanced technologies that can amplify not only participatory opportunities but disparities and potential social risks and harms. For example, in the CN project, the team expressly produced a trilingual site with interactive features, such as the game Ecocene, which uses AI-generated imagery to reimagine contributions, and co-developed the platform with a cross-section of audiences to ensure greater equitable representation. In the *NENP*

initiative, the iNaturalist app and website, which was used by young people to connect to a wider international community of naturalists, was noted by the project team to come with safety risks. Inherent in many digital communities, young people are contactable by external individuals, and images of young people are potentially made public on the platform. Strategies to limit user accounts to teacher settings, and a process of identifying and addressing online images of young people, balanced risks with benefits.

A related challenge is that of upskilling, which can be applied to volunteers, as a limitation to and a driver of meaningful participation, and to teams themselves that operate these projects. In NENP, Geographic Information System (GIS) map-based tools were widely used within the research department of the Natural History Museum; however, there was an upskilling requirement for the programme team of the NENP in creating GIS-based digital tools for participants, most of whom had never used GIS before. The DNP ran in-person transcription workshops at public libraries across the Northwest of England and produced STEM lesson plans and resources on the interdisciplinary work of Davy that were aimed at 11-to-14-year-olds.

The UCSS team, in partnering with the Citizen Science Academy, demonstrates that learning new skills can be a draw and help with volunteer retention. The Academy integrates educational programmes into projects, and upon completion, participants are given a certificate that attests to their new skills. The NENP centers green and digital skills development for young people as a programme goal, supported through expert educational and STEM partnerships to upskill teachers and facilitators. Offline activities are equally promoted so that equitable access and participation can be optimised.

FUNDING AND SUSTAINABILITY

Case study projects were established with government education funding or government research funding or both. The FAE programme, the UCSS service, and TB (subsequent to government and philanthropic funding) are internally funded, and they sustain some of their core funding with pro bono support. Specific tools and technical innovations were separately funded in the development and implementation phases of projects, although maintenance is presently resourced in house (e.g., UCSS, TB) or through partnerships (e.g., NENP).

The role of partnerships seems to be particularly key across the case studies in helping to acquire funding and in supporting sustainable pathways. The CN initiative, for instance, is co-led by two European natural history museums: Museum für Naturkunde Berlin and Muséum national d'Histoire naturelle in Paris. Lancaster University (host of DNP) are members of the Cambridge Digital Collections community alongside the Universities of Cambridge and Manchester, and the NENP is delivered by a consortium of partners and funded by the UK Government.

Sustaining a project beyond external funding periods was mentioned in several case studies. Post-funding support suggested reliance on internal resourcing and/or partnership opportunities, or diversified grant funding. Funding in a post-project phase was targeted to specific areas, such as digital infrastructure support and data platforms (TB, FAE).

Aside from the use of open tools and standards, the case studies highlight a range of sustainability processes in practice. For example, the UCSS team performed an in-depth needs assessment with an action plan for resources and support over time. Both CN and NENP school resources are designed to allow teachers to integrate the project independently into classrooms, thus broadening outreach beyond the project and embedding participation into learning contexts.

Socio-technical considerations of digital transformation in GLAM institutions where digital infrastructure may be under-resourced was a nuanced sustainability issue. For instance, FAE acknowledged that for cultural institutions to serve as trusted data intermediaries in AI development requires dedicated resources and expertise. However, cost-benefit analysis of certain approaches, such as crowdsourcing, demonstrated positive outcomes. According to the TB project, volunteers not only produced transcripts to a very high standard, but the process underlined that scholarly crowdsourcing can offer significant institutional cost savings realisable in the longer term (Causer et al. 2018).

REFLECTIONS ON MAPPING A CULTURE SHIFT

From the findings and analysis of our representative studies, we identified further considerations of both experiencing and supporting a culture shift and emergent possibilities. By "culture shift," we refer to changes in the shared values, beliefs, and behaviours of an organisation (Stephenson 2023). A culture shift in GLAM can be attributed to significant change in how these institutions operate and relate to their communities, embracing new technologies, and diversifying their collections and perspectives by actively co-producing with the public to foster social connection and new narratives. Not least, there is an opportunity to move away from traditional roles to support equitable and responsive public interest in areas, such as AI and social and environmental justice, for example (Avdikos et al. 2024; Cotter 2025).

The outcomes from knowledge co-production, reinforced by digitally enabled two-way and multimodal interactions, suggest that there were measurable and positive impacts for the organisations and their participating communities. Outcomes varied from collectively developing an open choral AI dataset and model (FAE) to activating children and youth in environmental stewardship (NENP) and approaches for higher visibility of diverse perspectives on ongoing environmental changes (CN).

In group meetings, authors themselves have also reflected on what a culture shift means to them and their organisation, and what this might represent, including facets of innovation (Butkevičienė et al. 2021; Eid and Forstrom 2021) leading to more impactful and relevant outcomes. Excerpts from the full case studies (Supplementary File 1: Appendix. Table S8) are provided as supporting statements to reflexive considerations. Several emerging shifts experienced and/or discussed by the GLAM representatives during this study are further articulated below.

DIGITAL CROWDSOURCING CAN CATALYSE A COMMUNITY OF PARTICIPATION

In TB, it is not the volume of participation but the community of participation (Causer and Terras 2014) that makes the transcriptions possible: "volunteers are willing and able to complete highly complex tasks in order to contribute to the production of scholarly research."

—Principal Research Fellow, formerly TB co-ordinator

For DNP, the notion of culture shift aligns with the institutional vision (Lancaster University Library) outlining an ambition to be "a library that brings our communities together to co-curate, co-create and share knowledge that leads to greater understanding, insight and innovation… The DNP has been a key way in which we have realised this part of our vision."

—Associate Director: Space, Experience and Innovation

EXPERIMENTING WITH FORMS OF INNOVATION IN KNOWLEDGE CO-PRODUCTION

NENP offers modalities of knowledge co-production both for online and offline participation supporting diverse learner-directed pathways at scale. For FAE, experimentation has addressed unbalanced and unfair dynamics in AI practices, such as co-production and data stewardship. The CN project combines innovative "pathways for more polyphonic storytelling and the incorporation of local perspectives in museum's collections as well as in scientific practices, thereby allowing more space for subjective representations, critical reflections, and the decentralized narratives of the Anthropocene" (Heyne et al. 2024).

— Lead research group and project lead

OPEN AND ACCESSIBLE DIGITAL MODALITIES

The UCSS couples its work to the wider practices of open science and responsible use of open source in its role as the university custodian of open science practices. Open and accessible tools, such as MediaWiki, have supported TB volunteers in accelerating the rate of transcription, widening digital access to Bentham's vast archive, and producing volumes of collected works.

In the NENP, "digital tools have also made project data more transparent and available—all participants can see (and download) all others' habitat maps and biodiversity observations. It is massively increasing the speed at which community science data are made available to participants."

—Lead for Community Science

POTENTIAL FOR SHIFTING CURATORIAL POWER AND AGENCY

In CN, participants become curators of collections and exhibitions, and contributors to enriched object information. In FAE, the Choral Data Trust Experiment allows for the distribution of power between contributors (for example, choristers) to the training of AI data and those who use the models (Ivana and Ding 2025). For the NENP, the shift that the team "have designed into this project is moving away from digital tools being used to 'reach people' or for unidirectional data submission or feedback, towards digital tools that serve the purposes, visions, and goals of the participants, beyond the boundaries of the project."

—Lead for Community Science

There is a critical background process of building trustworthiness in this context. For example, in CN there is an effort to refrain from distinguishing between "right" or "wrong" contributions, emphasising inclusivity and mutual trust, whilst in FAE there are direct efforts to foster trustworthiness across data, people, and organisations.

TRANSLATIONAL KNOWLEDGE CO-PRODUCTION

The UCSS, as a central point of knowledge-sharing in a research library and through partnerships with the Citizen Science Academy and groups, such as Co-production Collective, reinforces opportunities for translational knowledge co-production through practical embedding of participatory research skills.

CN draws attention to the social and cultural dimensions of existing museum collection practices, inspiring broader discussions and networks between practitioners, scientists of different disciplines, and society (Sturm et al. 2022). In the NENP initiative, a structured 5-step programme aims to change the way people see themselves within the knowledge-production system as an integral part of it (Burton et al. 2024) (See Figure 3).

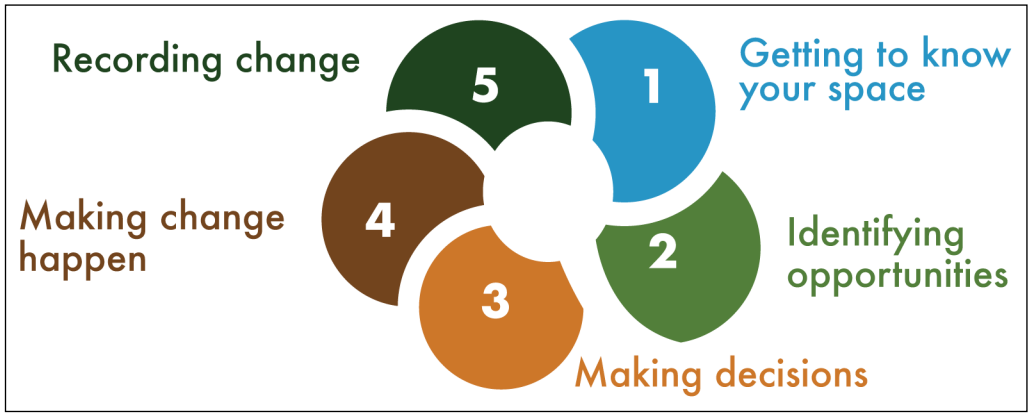


Figure 3 National Education Nature Park five step cycle © Department for Education.

COLLECTIVE LESSONS

ADAPTATION

The collective lessons of this research, scaffolded with the analysis, reflections, and case study examples, provide insights into how a digitally enabled participatory knowledge co-production can be initiated and progressed in GLAM institutions, as well as how it connects to translational outcomes (Ridge, Ferriter, and Blickhan et al. 2021). More immediately, the culture shift reflections highlighted above move us away from extractive forms of knowledge co-production to transformative and regenerative practices where co-production can serve wider purposes in the community and/or enable the community to continue to adapt the project, even after its core timeframe (Butkevičienė et al. 2021). This is evidenced, for example, in the FAE amplifying the potential for cultural institutions to serve as trusted data intermediaries beyond an exhibition. Digitally enabled modalities can strengthen these transformative and regenerative practices by enabling pathways for adaptation, for example, self-guided experimentation and learning, as in CN and NENP. Partnerships across the six case studies (CN, TB, NENP, UCSS, DNP, and FAE), including with participants themselves, are critical to this deeper, adaptive, and sustained engagement (Deupi and Eckman 2016; Hetland et al. 2020).

RECURRING CHALLENGES

We acknowledge that GLAM institutions still face recurring challenges to move beyond isolated pilot projects towards a genuine cultural shift if they want to. The strengths of bottom-up approaches and multi-stakeholder processes to policy-facing outcomes are highly desirable but challenging to achieve (Göbel et al 2019; Herzog and Lepenies 2022). General questions arise, for instance, of how far digital modalities have moved the dial on participation diversity in knowledge co-production (Poetz and Sauermann 2024). And how do digital modalities for knowledge co-production move the dial on "who" we are co-producing with (Eleta et al. 2019)? In the NENP, the programme is intended for every school, college, and nursery in England, and hence there is significant uptake in areas of deprivation but "we have not yet explored to what extent the digital elements are influencing/supporting this more diverse group of participants."

—Lead for Community Science

In a related and collective lesson, the case study initiatives demonstrate innovative approaches, yet many remain project-based, temporary, and/or dependent on individual actors. This can further reflect the sector's often limited capacity through funding, skills, or other mechanisms to pursue a longer-term program of innovation and/or to capitalise on newer digital innovations (Huang and Liem 2022). Sustained knowledge co-production is especially a challenge where digital modes of technology adoption are immature or evolving (Bowen et al. 2023). Similarly, we noted a shared recurring challenge of maintaining a project beyond an external funding period, requiring a reliance on diversified funding strategies. Funding for the digital transformation of GLAMs may have separate needs than those for sustainable digital infrastructures developed for knowledge co-production, for instance (Gooch et al. 2025).

MOVING TOWARDS A CULTURE SHIFT

Notwithstanding these recurring challenges, the six cases studies highlight that GLAMs can effectively support crowdsourced knowledge co-production approaches, mediated by digital modalities. For example, the design of the case study projects to "scaffold" beyond a task-driven interface and agenda (Ridge 2013), with digital modalities enabling dialogue, interaction, and connection between experts and citizen scientists, as well as between participants themselves, were characteristic features

of the studies. As such, this scaffold design potentially strengthened reciprocal value among participants, as captured in the authors' reflections. Reciprocity was overwhelmingly linked in the case studies to attribution, but also knowledge exchanges, shared scholarship, and skills acquisition. Together, these examples counter the notion that volunteers in online and digitally-enabled crowdsourced citizen science participate with lower agency (Strasser et al. 2019).

What this research inevitably reveals about institutional change in GLAMs will require further investigation and a broader sample size, which is beyond the current scope. However, the six case studies collectively reveal an institutional culture shift in which deeper and sustained participatory approaches have become part of their "business as usual." This is evidenced in institutional strategies and project missions articulated across the case studies and in translational efforts supporting their respective GLAM communities in digital modalities of knowledge co-production, each reinforced within the context of a shared, significant, and larger goal (Holley, 2010).

LIMITATIONS

While we strived for methodological rigor in this article through collaboration and across disciplines reflecting on digital modalities of knowledge co-production in GLAMs, we acknowledge the inherent limitations of case study methods. The basis for evidence was limited to a small sample, for example, in GLAM representation, in the range of digital modalities and co-production scenarios, as well as in participation diversity and geographic scope. Most case studies describe active projects, so there was not a ready baseline of past projects to determine culture shift measures. Nevertheless, the collective approach respects the socio-technical strengths and real-world contexts of the case studies. It is also an exploratory approach, justifiable by the relative newness of the research topic in the recent literature, leading to a foundation for further research and practice.

CONCLUSION

Building on a set of real-world case studies and reflexive considerations, this article has sought to advance an initial articulation of culture shift in GLAM institutions in their support, promotion, and empowerment of crowdsourced knowledge co-production using digital modalities.

The six case studies highlight, among the findings, that crowdsourced knowledge co-production using digitally-enabled two-way and multimodal participation can help scale, reinforce, re-shape, and strengthen these processes. There is also the potential for participating communities to adapt crowdsourced knowledge co-production projects, perhaps even beyond their institutional timeframe.

The identified culture shift among the study group of GLAM institutions suggests that such forms of participation can be more effectively sustained if operationalised through institutional missions ("business as usual") and underpinned with a clear shared goal. However, the conditions by which this can be successfully maintained, whilst ensuring inclusive access, benefit-sharing, and public value, has yet to be more fully understood. So, this is by no means a radical shift yet, but we are, perhaps, on a trajectory towards it.

DATA ACCESSIBILITY STATEMENT

This study is based on publicly available information. Case study data are provided as supplemental material.

SUPPLEMENTARY FILE

The Supplementary file for this article can be found as follows:

- **Supplemental File 1.** Appendix. DOI: https://doi.org/10.5334/cstp.937.s1

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COMPETING INTERESTS

MH serves as the Associate Editor-in-Chief of *Citizen Science: Theory and Practice* and AB serves as an Associate

Editor, although neither were involved in the review of this manuscript. No other competing interests are declared among the authors.

AUTHOR CONTRIBUTIONS

AB, MH: conceptualisation, design, methodology, data collection, analysis, original draft writing, review, and editing; KW: case study design, methodology, analysis, review, and editing. All other authors contributed equally to case study design, data collection, review, and editing.

AUTHOR AFFILIATIONS

Ann Borda orcid.org/0000-0003-3884-2978
University College London, United Kingdom; The University of Melbourne, Australia
Muki Haklay orcid.org/0000-0001-6117-3026
Department of Geography, University College London, United Kingdom; Centre d'Ecologie et des Sciences de la Conservation (CESCO) MNHN, France
Kirsty Wallis orcid.org/0000-0002-9570-6174
Library, Culture, Collections & Open Science (LCCOS), University College London, United Kingdom
Lucy Robinson orcid.org/0000-0001-8604-3447
Natural History Museum, United Kingdom
Victoria Ivanova
Serpentine Galleries, London, United Kingdom
Tim Causer orcid.org/0000-0001-5550-0561
Bentham Project, University College London, Faculty of Laws, United Kingdom
Tim Leonard orcid.org/0000-0002-9661-7800
Lancaster University, United Kingdom
Susanne Hecker orcid.org/0000-0001-7398-5806
Museum für Naturkunde – Leibniz Institute for Evolution and Biodiversity Science, Germany
Elisabeth Heyne orcid.org/0000-0001-7699-015X
Museum für Naturkunde – Leibniz Institute for Evolution and Biodiversity Science, Germany
Ulrike Sturm orcid.org/0000-0001-6446-6051
Museum für Naturkunde – Leibniz Institute for Evolution and Biodiversity Science, Germany
Sharon Ruston orcid.org/0000-0002-3864-7382
Manchester Metropolitan University, United Kingdom

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