D3.6 Quality Assessment Report

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EXECUTIVE SUMMARY

Ensuring high-quality user experiences with digital cultural collections and tools requires adherence to key guiding principles, and an iterative approach of assessment and improvements. In the EUreka3D-XR project, there was a close collaboration between the consortium partners, formed by cultural heritage experts (content providers and holders who know their collections in depth and define the stories they want to deliver), and technology partners with significant experience in easy-to-use tools for managing digital collections. This collaboration was successful in delivering high-value outputs: specifically, the tools made available to cultural heritage curators to create XR experiences, and the demonstration applications for storytelling, aimed at on-site and online visitors and end users.

This Deliverable D3.6 (*Quality Assessment Report*) documents the strategies implemented to ensure quality for these project outputs, according to requirements that were jointly determined by the consortium partners:

- **Accessibility**: Content must be usable by diverse audiences, including those with disabilities, through adherence to standards such as the Web Content Accessibility Guidelines (WCAG).
- **Reliability**: Systems should function consistently, without technical glitches that disrupt engagement. This also includes addressing less evident aspects which may jeopardise user experience; for example, 3D models showcased in the apps should load swiftly on various devices without overwhelming users with unnecessary controls or long waiting times.
- **Usability**: This entails intuitive navigation and clear instructions for both the curators of the XR experience and the end-users who access it.
- **Accuracy and integrity**: Cultural heritage demands accurate representation; digitised objects must retain historical authenticity and full holistic documentation, while employing innovative visualisations, reconstructions, or simulations when appropriate.
- **Stakeholders' input**: Iterating design based on feedback from creators, external experts, and end-users ensures relevance across use cases and contexts.

By embedding these principles early on into project workflows, from initial planning through iterative development cycles, the tools of the project and the demonstration scenarios delivered XR experiences that respect cultural heritage and its memory, while embracing storytelling technologies that are engaging for all audiences.

The report is organised into the following chapters, featuring sections dedicated to the quality assessment measures implemented for the project’s various outputs. These are complemented by reflections on the feedback gathered throughout the project:

- Introduction
- Data quality
- Consistency of experience - the EUreka3D Data Hub and its extensions
- Accessibility and user experience - the EUreka3D-XR tools
- User manuals, documentation, and dissemination
- User feedback
- Conclusion

1. INTRODUCTION

Quality is a multifaceted concept that is considered at every stage of the EUreka3D-XR project. In the context of digital cultural heritage and extended reality (XR), quality cannot be reduced to a single technical metric. It encompasses the fidelity and integrity of 3D content, the completeness and correctness of metadata and paradata, and the overall quality of experience provided to users interacting with tools, infrastructures, and applications. All these aspects contribute to the reliability, usability, and long-term value of digital assets within a broader ecosystem.

From a data perspective, quality relates to both the technical and visual fidelity of 3D models, based on the robustness and completeness of associated metadata and paradata. In this regard, the EUreka3D-XR project builds upon the foundations established in the prior EUreka3D project and aligns with the VIGIE 2020/654 Study on quality in 3D digitisation of tangible cultural heritage[1], which serves as a reference framework for high-quality digitisation practices. For 3D models, this entails geometric accuracy, resolution, and structural integrity. For metadata, it requires consistency, completeness, and semantic clarity to support discovery, interoperability, and contextual understanding. For paradata, quality involves precise documentation of processes, equipment, provenance, circumstances, and contextual information related to the creation of digital assets.

Beyond the data itself, quality also encompasses the quality of experience when the digital assets are consumed directly (for example, through Europeana) or integrated into end-user applications and XR experiences. In this context, quality metrics include accessibility, usability, and consistency of interfaces for end users. For application developers, additional factors such as a coherent deployment platform, reliable data interfaces, and a unified login experience are essential. Finally, the availability and clarity of documentation play a crucial role in enabling adoption and supporting effective reuse.

Given its multifaceted nature, the EUreka3D-XR project does not treat quality as a standalone task, but rather as an operational philosophy embedded throughout project execution. Deliverable D3.6 (*Quality Assessment Report*) aims to document and assess how quality is ensured across these different dimensions within the project. The purpose of this deliverable is reflective and evaluative: it reports on the mechanisms, approaches, and practices adopted to achieve and maintain quality throughout project implementation. It does not aim to define guidelines or best practices for external audiences; those aspects are addressed separately in Deliverable D3.7 (*Formats and Quality Guidelines Report*) and Deliverable D3.8 (*Paradata and Sustainability Report*), which translate project experiences into recommendations and guidelines for external audiences.

This document, therefore, focuses on analysing how quality is achieved in practice within EUreka3D-XR. It examines data quality (content, metadata, and paradata), consistency of experience through the EUreka3D-XR Data Hub, accessibility and user experience of the developed tools, supporting documentation and dissemination efforts, and feedback gathered from users. By structuring these perspectives into a coherent assessment, the deliverable provides insight into the project’s internal quality assurance approach and lays the groundwork for the more prescriptive outputs that follow in subsequent deliverables.

[1] European Commission. *Study on quality in 3D digitisation of tangible cultural heritage*. 2022. https://digital-strategy.ec.europa.eu/en/library/study-quality-3d-digitisation-tangible-cultural-heritage

2. DATA QUALITY

Data quality in cultural heritage refers to the degree to which information about cultural heritage assets is accurate, complete, consistent, reliable, and fit for use by the multidisciplinary society. It ensures that data describing objects, sites, collections, and intangible heritage can be trusted for research, preservation, management, and public access. Key dimensions of data quality include accuracy, authenticity, precision, interoperability, sustainability, long-term value, and timeliness, among others.

Data quality is a misunderstood concept within the field of 3D digitisation in cultural heritage, frequently equated with the number of downloads by users, the visual fidelity of outputs rather than the quality of data and information used in the creation of the end 'product', i.e. the 3D model. Regardless of how the 3D model is deployed, it is only the vehicle for transmission of information, whether that be geometrical, historical or, in the case of experiential learning, a way to engage the visitor with the subject of the visualisation, of which the 3D model is only one of several components. The digital asset cannot convey all the information to the viewer; indeed, it would be counterintuitive to the objectives of a visualisation to do so. Rather, it must be 'fit for purpose'; that is, created to support the aims and objectives of the visualisation and experience detailed in the project's use case and development specification documents. Data quality is inherently part of the digitisation process; it cannot be added post-digitisation.

Quality must be embedded in standards and documentation requirements and not assessed solely on final outputs. Data quality must be understood as a governance issue that spans the entire digitisation lifecycle: from planning and procurement to acquisition, processing, deployment, and long-term preservation. How a programme of digitisation is undertaken, under what circumstances, and through what processes data is captured and transformed into a 3D digital asset, is, therefore, vital to establishing confidence in the output of digitisation and in understanding the appropriate deployment of assets produced.

This subject is discussed in the aforementioned *EU VIGIE 2020/654 'Study on quality in 3D digitisation of tangible cultural heritage'*, which considers 75 parameters that must be taken into account to provide evidence that the digitisation was undertaken under the best possible conditions to produce the final results. Through documenting the process, a record of quality and provenance for the dataset can be provided from which 3D assets can be confidently created, depending on their specific use case. It should be noted that one of the outputs of the 3D digitisation process is, de facto, an archetypal 3D model based on the preconditions of the digitisation programme. Understanding these processes, the complexity of the digitisation directly informs the quality of the 3D component produced.

The documentation of digitisation is comprised of a 'trinity' of data records:

1. **Data**: the captured dataset, sometimes just called data, including both the data acquired through the digitisation process and the archetype model
2. **Metadata**: descriptive and technical information for the file data
3. **Paradata**: the documentation of circumstances, decisions, processes and transformations made during the creation of the File Data and resulting archetype model.

The trinity is a documented history of the digitisation process and should represent a transparent record that provides trust and confidence in the data quality and the context in which the digitisation was undertaken. This documentation:

- Enables auditability and accountability (FAIR and CARE data principles)

- Supports reuse and redeployment of data
- Reduces duplication of digitisation efforts
- Safeguards long-term data integrity
- Strengthens cultural heritage preservation strategies

Without a well-documented provenance, Cultural Heritage Institutions (CHIs) risk data degradation, misuse, or costly re-digitisation.

Specifically addressing the question of reusability, well-documented digitisation mitigates many of the challenges surrounding the development of 3D assets that are fit for purpose, providing original datasets and comprehensive parameters to maintain an understandable, useable and defendable 'ground truth' from which new appropriate 3D assets can be derived or examined to ascertain if the context of the digitisation is suitable for the intended development based on its technical specification and use case.

For example, digitisation was undertaken to create a 3D model of an object held by a CHI in storage as part of their 'digital transformation strategy'. Two different reuse cases wish to use the model:

- A conservator seeking to understand the geometry, materials and colour fidelity of the digitised object.
- A curator seeking to use digitised objects as part of an XR experience engaging visitors with their CHI collections.

Both are legitimate uses of the same source object but are significantly different in their requirements. Without appropriate documentation placing the digitisation in context, the reuse of both data and the archetype model becomes problematic.

In the first case, digitisation would likely need to be repeated to ensure that data could be verified, and the granularity of the 3D model and textures would be high enough for study. In the second case, the 3D asset may be too 'heavy' (high polygon count, high fidelity imagery, etc.) for use, requiring the re-digitisation or, more likely, the refactoring of the extant model to make it fit with technical constraints and requirements.

If the original digitisation process had been documented, even though the available archetype model may not have been appropriate in either case, the file data, metadata and paradata associated with it would have provided a basis to assess what resources existed, how they were used and for what outcome and, if the quality and integrity of the dataset were viable for reprocessing to achieve the new objectives.

In the second case, the most likely solution would have been to refactor the archetype model and lose both evidential integrity and degradation of data fidelity in an attempt to fit the existing model to the new specification. If the original digitisation had been documented well, the lightweight model required for implementation could have been reprocessed from existing file data, rather than refactoring the archetype model with the associated risks. This is particularly important if the second-generation model is subsequently reused, carrying little or no provenance of its own and amplifying any errors; in such cases, there is a risk that an adapted model is mistaken for the authoritative source model.

Implementing and maintaining robust documentation supporting the digitisation process is not a task for its own sake, nor one of simply technical best practice; it contributes to the digitisation's sustainability strategy. While the technological implementation of the 3D asset may be superseded, and even the 3D model representation may be unable to take advantage of improvements afforded by such change, the data quality afforded by well-documented datasets allows future reinterpretation and reprocessing of baseline data without re-digitisation, as well as continued alignment and engagement with stakeholder objectives and improved public engagement with trusted assets as platforms evolve. This not only makes the most of the investment in a digitisation programme, but also supports responsible stewardship of assets created through public funding.

Data acquisition for analogue 3D content (i.e., physical objects as opposed to those created through reconstruction or generative AI) used within the EUreka3D-XR case studies was captured using the VIGIE 2020/645 guidelines outlined in the EUreka3D publication '3D Digitisation Guidelines: Steps to Success'[2], based on the EU VIGIE2020/654 Study. All necessary metadata and paradata documentation was completed for all captured data, meeting the specific requirements of each case study.

From this core guideline-compliant dataset, each case study developed the 3D content necessary to fulfil the specification for each scenario. This was (and can only be) achieved through collaboration between the main scenario partners (i.e., CRDI; BIBRACTE and CUT) and the respective experienced developers, making sure the vision for the experience is achieved within what is technically possible. The 3D content of each of the XR experiences developed for the EUreka3D-XR project, therefore, represents the correct 'quality' for the scenarios as part of this negotiation process. However, the true quality of the asset developed to support the scenario and experience is the ability to revisit the data from which the 3D content is derived. This ability to trace back the resources and means of production is, in itself, a form of sustainability, allowing experiences to be refreshed, assets to be improved and engagement to be refined as technology advances, allowing more data to be exposed in line with the stakeholders' vision.

With the rise and rapid development of generative artificial intelligence (GenAI), the question of confidence in data quality and provenance is brought into sharp contrast. Within the creative sector, there is great concern about how GenAI is already impacting both economic and societal factors for both producers and consumers alike. Within the cultural heritage sector, in particular, we are already seeing the push to use GenAI as a shortcut to developing digital assets, which raises similar questions in data governance, portraits of the past and the value of cultural heritage. Despite the use of GenAI being very limited and highly controlled in the EUreka3D-XR project, its ethical concerns have been addressed by the project's Ethics Board and key considerations are reflected in Deliverable D1.6 (*Ethics issues mitigation measures*).

As data quality relies on transparency of process, exemplified through the data trinity, we must seek new methods and approaches if we are to leverage the power of this unproven technology into our practice in a meaningful and beneficial way. Concerns surrounding GenAI include:

- Lack of transparency regarding training datasets
- Uncertainty around authenticity, bias and data governance
- Limited peer review of model parameters and algorithms within the cultural heritage domain
- Ambiguity in the documenting of AI-generated components within the paradata record
- Legal uncertainty regarding the copyright status of fully AI-generated 3D assets

The use of GenAI within cultural heritage is unlikely to diminish, and therefore, investigation into the documentation standards for AI-assisted 3D production is urgently required to establish transparency and accountability requirements for data quality, provenance, and trust.

[2] '3D Digitisation Guidelines: Steps to Success'. 2024. https://eureka3d.eu/wp-content/uploads/2024/06/3D-digitisation-guidelines-EUreka3D.pdf

3. Consistency of experience: the EUreka3D data hub and the deployment infrastructure

As a key component of the EUreka3D-XR project, the EUreka3D Data Hub is designed to provide a coherent, reliable, and trustworthy environment for storing, managing and publishing cultural heritage data. A central objective of the system is to provide a unified experience across tools and services, thereby lowering complexity for both end users and Content Providers. It is common for users of heterogeneous research infrastructures to be confronted with multiple login systems, deployment practices and inconsistent access procedures which often lead to fragmentation, unpredictable behaviour, and reduced trust. The EUreka3D Data Hub addresses these challenges by harmonising core components for the user experience. This design is not merely a technical aggregation of services, but a coherent operational environment that delivers a unified experience for users.

Quality in the EUreka3D Data Hub is achieved through:

- Architectural alignment, discussed in Section 3.1.
- A unified login experience, described in Section 3.2.
- FAIR and reusable 3D data, addressed in Section 3.3.
- A modern, unified application deployment process, explained in Section 3.4.

3.1 Architectural alignment

The architectural alignment comes from the system's underlying components, which directly support the European Open Science Cloud (EOSC)[3] objectives, including interoperability, reliability, and FAIR principles. By embedding these principles into the foundation of the components, rather than treating them as external compliance requirements, the platform ensures that quality is inherent to its operation. The result is an ecosystem in which CHIs act as Content Providers as well as downstream end-users, interacting with a stable and predictable environment.

Service reliability offered in the infrastructure is safeguarded through defined Service Level Agreements (SLA), and Operational Level Agreements (OLA) with providers, ensuring clear responsibility allocation, monitored availability targets, and structured incident management processes.

3.2 Unified login experience

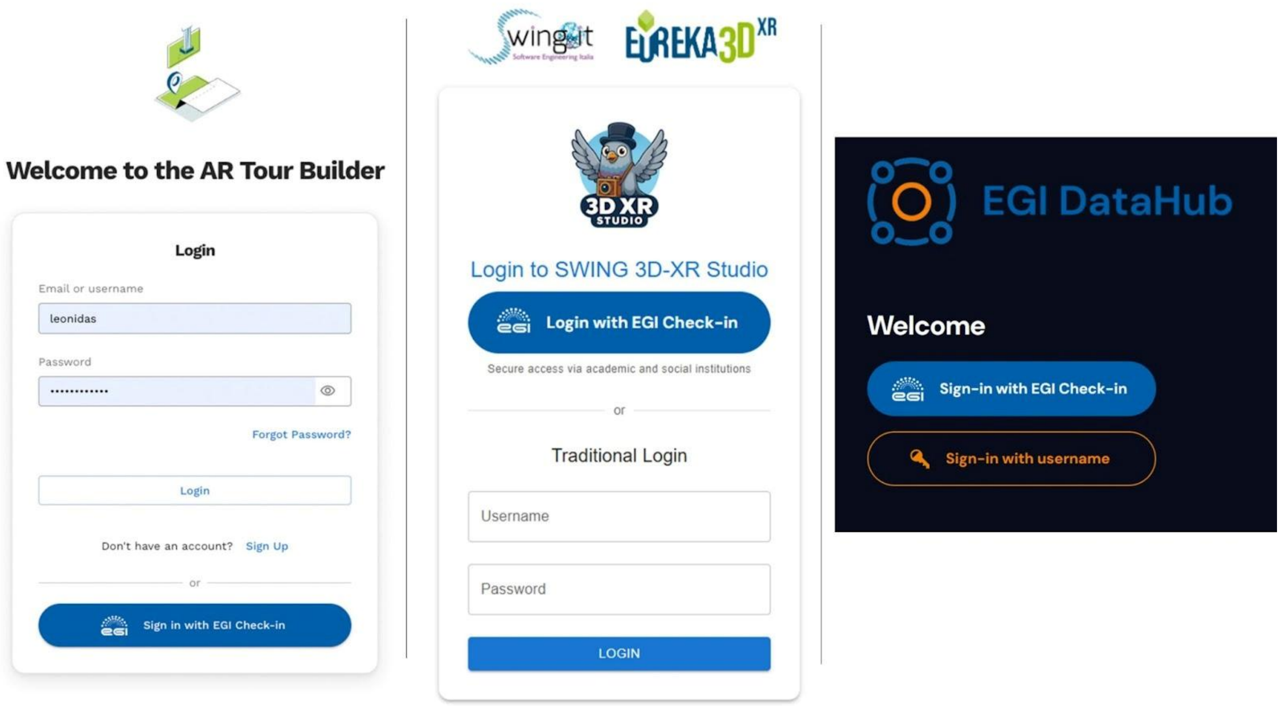
Trust in a shared data space begins with reliable identity management and secure access. The EUreka3D Data Hub implements a federated authentication and authorisation infrastructure provided by EGI Check-in. This approach enables users to authenticate through their own trusted identity providers (idPs), while maintaining consistent access semantics across all deployed services. The authentication process becomes predictable and familiar, reinforcing confidence in the system's security and governance. Check-in is federated in eduGAIN as a service provider, publishing REFEDS RnS and Sirtfi compliance.

The EGI Check-in service provides identity and access management to facilitate users to access community services and resources securely. The EUreka3D community can be managed from a centralised point, while

[3] European Commission. 'European Open Science Cloud (EOSC)'. https://research-and-innovation.ec.europa.eu/strategy/strategy-research-and-innovation/our-digital-future/open-science/european-open-science-cloud-eosc_en

combining user attributes originating from various authoritative sources and delivering them to the connected service, all of which directly strengthens the framework for GDPR compliance.

A seamless authentication experience is fundamental to usability and trust. An interesting feature that Check-in's approach offers is Single Sign-On (SSO). When users need to access different yet related systems, it is very tedious for them to be forced to authenticate separately at each of the systems they access. Moreover, this is not only inconvenient for users, but also becomes a problem if the resources the users access are federated. SSO addresses this problem by allowing the user to authenticate once and be able to access resources that are located in disparate systems, without the need to enter user credentials for each individual application or service. Check-in implements this as a trusted third party that authenticates the user and is able to share this state with a set of trusted applications protecting the resources. SSO helps users of the EUreka3D Data Hub to access its different services, such as the data management system provided by Data Hub, the AR Tour Builder and the 3D XR Studio tool, without the need to login separately to each of them, or even to keep different accounts or user credentials for each of them. The login experience in the EUreka3D Data Hub ecosystem offers a unified way to log in, and an recognisable login button (see figure below) that ensures a consistent design and experience across different applications and systems.



Login pages for AR Tour Builder, 3D XR Studio tool and DataHub

The trust framework of the EUreka3D Data Hub enhances interoperability. Because authentication is handled through a shared and standardised framework, services can be integrated without requiring bespoke access solutions. This reduces integration effort for developers and prevents the proliferation of isolated identity silos, which are a common source of fragmentation in distributed infrastructures. Check-in supports the most relevant industry-standard mechanisms for authentication and authorisation, which are widely adopted standards and open technologies, such as OIDC/OAuth, SAML and X.509, facilitating interoperability and integration with existing AAI services.

Finally, Check-in is compatible with the EOSC AAI Federation and is a registered member of it. EOSC runs on a Federated environment of systems and services. The purpose of the Authentication and Authorisation Infrastructure in EOSC is to support the FAIR principles for data and services while enabling high-trust collaborations to be established and maintained with little or no friction to the end user. AARC (Authentication and Authorisation for Research and Collaboration) is an initiative that addresses federated access through authentication and authorisation mechanisms in research and e-infrastructures, serving as the foundation for the EOSC AAI through its Blueprint Architecture. As Check-in is part of this ecosystem, all the services integrated with the EUreka3D Data Hub are accessible to all EOSC users in an interoperable and trusted manner: it allows users to authenticate with a large variety of idPs, providing a simple and integrated method to guarantee service access for EOSC users in accordance with their defined access policies.

3.3 Enabling FAIR and reusable 3D data

The main data assets in the EUreka3D Data Hub are 3D cultural heritage models and its associated data, such as metadata and paradata. Quality assurance in this context involves more than technical accessibility. The EUreka3D Data Hub supports clear publication workflows, persistent access mechanisms, and consistent permission handling, all of which reinforce the FAIR principles. Data made available through the system is not only accessible but presented within a framework that enhances discoverability, interoperability, and reuse.

By adopting Persistent Identifiers (PIDs) delivered by the European initiative EUDAT's B2HANDLE[4], the EUreka3D Data Hub ensures the rigorous management of PIDs and essential metadata, transparently for content providers. This feature strengthens the FAIR principles by assigning globally unique and resolvable references to digital objects, ensuring they remain reliably findable and citable over time. By linking identifiers to up-to-date metadata and access information, they support accessibility even if storage locations change. Because PIDs rely on standardised frameworks, they can be embedded consistently in metadata records. At the same time, their persistence underpins long-term reuse by supporting stable citation, provenance tracking, and accountability, thereby reinforcing trust and sustainability within a federated research ecosystem.

Metadata in the EUreka3D Data Hub uses the Europeana Data Model (EDM) rather than a proprietary model. By adopting this recognised standard in the cultural heritage field, the system ensures semantic interoperability, facilitates seamless data exchange and enhances comprehension across external systems that consume or integrate the data.

All metadata records in EUreka3D Data Hub are published through a publicly accessible OAI-PMH endpoint, which is another essential aspect of the user experience. Herein, 3D datasets are exposed to external systems, such as Europeana, through standard and structured mechanisms that are transparent for content providers. The result is an ecosystem in which 3D data can be shared, reused, and built upon without requiring custom solutions for each new dataset.

3.4 Unified application deployment

Behind the visible user experience, operational consistency is a critical determinant of quality. The developers of EUreka3D-XR services use a common Version Control System (VCS) to publish their source code as open source. Public repositories on GitHub are designated and configured for this task, according to code management best practices: version control, change traceability, issue management, and technical

[4] EUDAT Collaborative Data Infrastructure. 'B2HANDLE'. https://eudat.eu/service-catalogue/b2handle

documentation. The repositories host the latest stable version of the software, any previous and subsequent evolutionary releases, as well as the documentation related to the specific tool.

The application code is compiled and packaged into container images, which are ultimately stored and published in the EGI Artefact Registry via an automated CI/CD pipeline. These artefacts are then deployed to a Kubernetes cluster, which is a set of machines that run containers whose number can be dynamically adapted to the applications' demand. Two different environments are used: Staging, for testing, and Production, clearly separating the responsibilities of each. If a container stops working, Kubernetes detects it and restarts the number of redundant processes to meet the expected performance. This deployment process achieves reproducibility across all environments, controlled update processes, and greater resilience. As a result, service behaviour becomes more predictable, reducing the risk of disparity between services and avoiding inconsistencies that could negatively affect user trust.

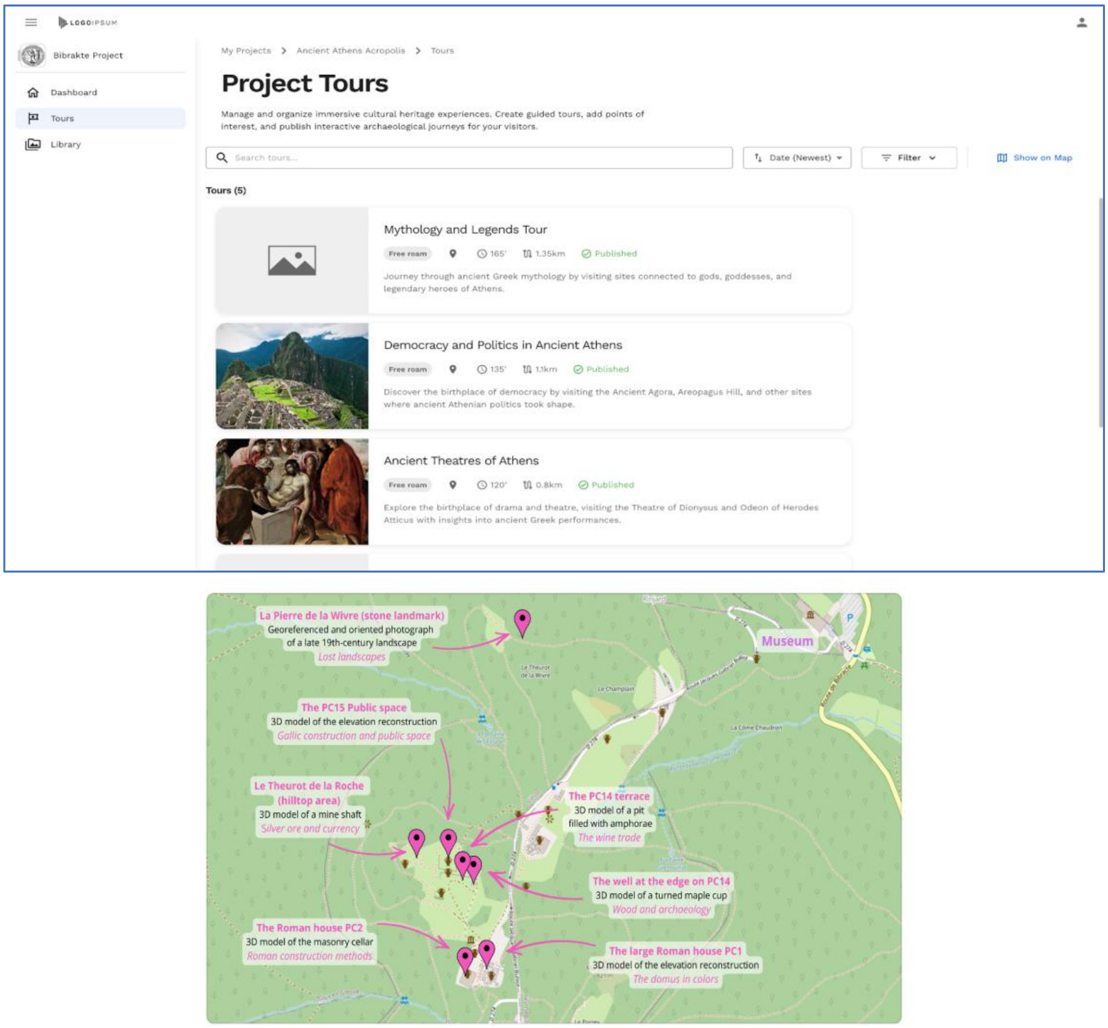
The 3D generation pipeline uses a dedicated infrastructure due to the need for GPU resources, which has been specifically designed to meet the needs of the 3D XR Studio tool. This configuration ensures adequate performance, controlled scalability, and operational continuity. Since the Avatar Builder tool provides a workflow rather than a dedicated standalone application, it does not require deployment within the common application architecture.

The whole solution ensures long-term sustainability thanks to the reliability of the platform, reduced infrastructure management costs, and the ability to promote reuse, transparency, and dissemination of project results within the scientific and technological community. The adoption of a widely recognised standard also facilitates distributed collaboration, increasing the productivity of the development team and the replicability of the solutions.

4. Accessibility and user experience: the EUreka3D-XR tools

4.1. AR Tour Builder

The AR Tour Builder web platform has been developed following widely accepted UI design principles, with the aim of supporting clarity, usability, and consistency across typical user workflows. The interface layout, navigation structure, and interaction patterns have been designed to be generally intuitive for a broad range of users without the need for having particular digital or technical skills, while remaining flexible enough to accommodate future refinements based on user feedback and evolving requirements. The platform also incorporates responsive design approaches, so that core functionality can be accessed across common device types and screen sizes, subject to normal variations in browser and device capabilities. In addition, the platform has been designed taking into account a baseline set of accessibility considerations, such as the use of readable font sizes, adequate colour contrast, and clear visual hierarchy. Feedback provided by cultural heritage professionals from the Bibracte site, where the pilot is conducted, led to various improvements, resulting in a more intuitive and user-friendly tour design process.



Screenshots from the AR Tour Builder web application:
a) List of tours under a project and b) Points of Interest positioned on a map

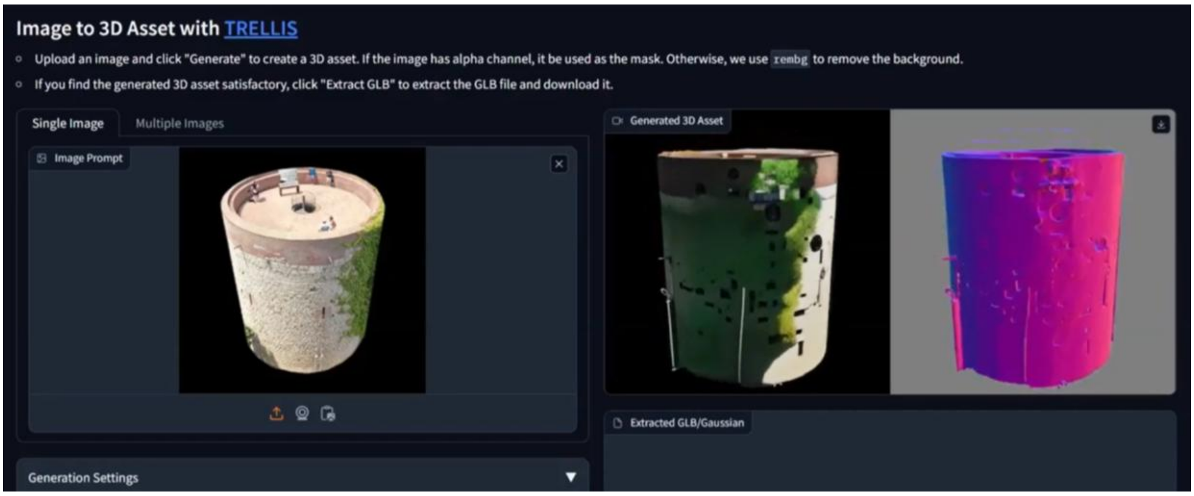
4.2. AR Tour Experience

The AR Tour Experience mobile application has been designed to support the delivery of cultural heritage content through a combination of 3D objects, images, and textual information in a unified viewing experience. The application structure aims to balance visual richness with usability, allowing users to access contextual information while interacting with AR elements in real-world environments. The implementation is intended to operate on a broad range of Android mobile devices, while acknowledging that performance and visual fidelity may vary depending on device specifications and environmental conditions. From a user experience perspective, the application design follows mobile UI good practices, including clear navigation, legible text presentation, and attention to visual contrast in key interface elements. These design choices are intended to support usability in typical on-site conditions and the feedback received during the testing and evaluation sessions at the Bibracte site was taken into consideration for providing an overall smooth and engaging user experience.

Screenshots of the AR Tour Experience app: a) Selection of content associated with a point of interest; b) Positioning of a 3D within the physical environment

4.3. AI 3D Builder

The AI 3D Builder was designed with accessibility for non-technical cultural heritage professionals as a primary objective. Built upon Microsoft Trellis technology, the pipeline provides an interface that allows archivists to generate 3D models from 2D image collections without requiring advanced technical skills. To optimise usability, the development team implemented comprehensive guidelines covering input photo quality and best practices for achieving optimal results across various conditions, such as quality issues. The workflow emphasises a crucial human refinement stage following AI generation, recognising that automated outputs require curatorial expertise for cultural heritage accuracy. User feedback during the Girona pilot development revealed the importance of clear documentation on the upload and export processes as well as during the resulting model and texture refinement through 3D model and photo editing software. The tool's primary challenge centred on balancing automation with the need for expert validation, a lesson that informed the creation of more explicit guidance on when and how curators should intervene to refine AI-generated models.



Creating 3D model of a medieval tower with the AI 3D Builder pipeline

4.4. 3D XR Studio

The 3D XR Studio (comprising both web and mobile applications) was developed with an approach specifically designed to reduce technical barriers for cultural heritage curators creating AR experiences. The dual-component system allows curators to design experiences through an intuitive web interface with map-based POI positioning, while the mobile component enables both end-user access and on-site refinement by administrators. Key accessibility decisions included implementing React-based graphical interfaces with visual tools for precise 3D model placement (position, rotation and scale) that require no programming knowledge, and ensuring compatibility with the EGI Single-Sign-On authentication system used across the EUreka3D Data Hub.

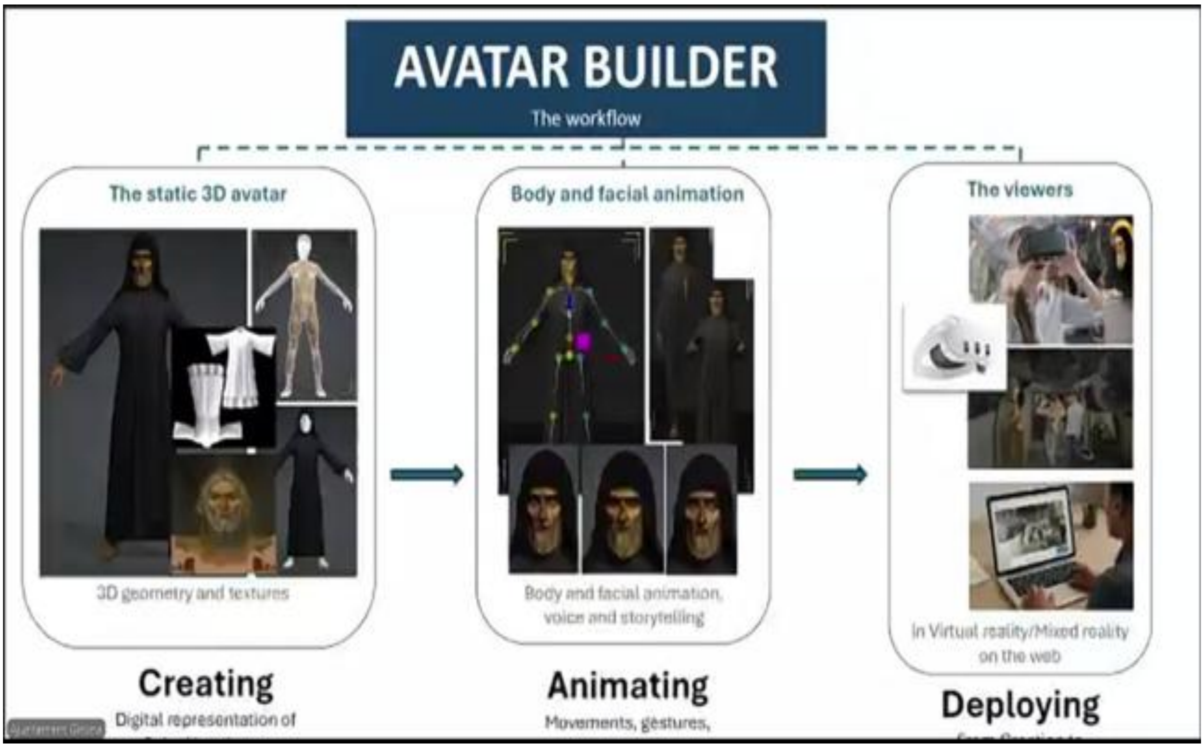
General view on the WebApp with the Girona walls 3D model positioned on the map.

During the development phase of the Girona pilot, usability testing revealed the need for flexible model management features, leading to the implementation of a Library interface that supports both external content sources (Europeana, EUreka3D Data Hub) and direct file uploads. Lessons learned emphasised that curator workflows benefit most from real-time preview capabilities and the ability to test positioning on-site via the mobile app before public deployment. Similarly, the path points generation process and point of interest feature were carefully refined based on valuable feedback from the Content Partner (CRDI).

4.5. Avatar Builder

The Workflow

With a focus on non-technical end users like cultural heritage professionals, the Avatar Builder was designed as an accessible, modular workflow for the creation, animation, and deployment of virtual humans. Three essential principles guided the pipeline's tool selection: open-source availability, standard format usage, and ease of learning. All of the chosen tools are open ecosystems and free to use, guaranteeing sustainability and lowering technological and financial barriers. In order to facilitate interoperability across engines, web platforms, and virtual reality environments, content is exported in commonly used standard formats, such as glTF and Fbx. With detailed instructions, diagrams, and recorded demonstrations, the workflow has been well documented, making it possible for non-experts to follow it without needing to know complex technical details. Understanding that cultural partners are typically not technical experts, every design choice was made with the end user in mind, from tool selection to file organisation and automation of repetitive tasks. The Avatar Builder's emphasis on documentation, modularity, and clarity reflects the project’s dedication to long-term usability and accessibility-related design decisions.



Avatar Builder workflow

The XR Experience

The XR experience was created in two complementary configurations: a web-based viewer created by MIRALab using Babylon.js and an immersive VR application for Meta Quest 3. Offering both immersive and non-immersive modes of engagement, this dual approach was a deliberate accessibility choice. To convey the life of Saint Neophytos and the history of the Enkleistra, one of the project's key pilots or reusable scenarios, the narrative scenario was co-designed with the cultural partners. Despite offering a wealth of historical content, user testing identified significant ergonomic limitations in virtual reality: lengthy audio stories can wear users out, interfere with immersion, and take away from the overall experience. To preserve comfort and engagement, the VR version was condensed to approximately three minutes as a practical design decision, concentrating only on the most pertinent narrative components. A longer and more in-depth story without cognitive overload is made possible by the web-based viewer's ability to incorporate complementary text overlays and extra contextual information alongside the animated scene.

Lessons learned during development and testing highlight the importance of adapting content to the medium rather than directly transferring it. Immersive VR requires concise storytelling and strict timing control to preserve user comfort and attention, whereas web-based environments can support layered information and extended narratives. Providing multiple modes of access significantly improves inclusivity, as users can choose the experience that best matches their technical capacity, physical comfort, or contextual constraints. Overall, the design choices demonstrate that accessibility in XR is not limited to interface simplification, but also involves narrative structuring, duration management, hardware flexibility, and continuous collaboration with content owners to balance historical accuracy with experiential quality.

4.6. Harmonisation

EUreka3D-XR Apps Design Guidelines

Design Guidelines have been created to ensure visual coherence, usability, and recognisability across the project tools. The guide establishes a shared design language that strengthens the identity of the project while supporting both end-users (visitors) and CHIs engaging with the applications.

Icon draft mock-up displayed on a mobile screen

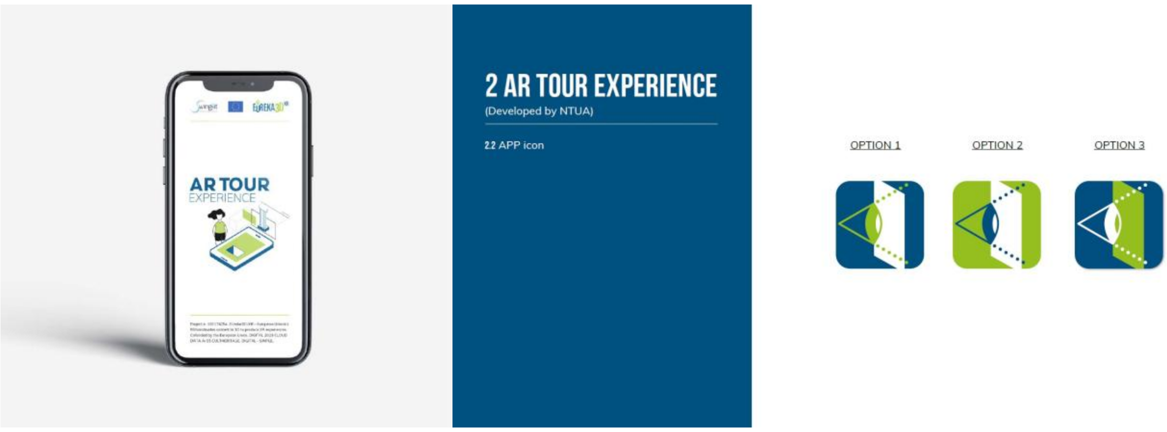
The main objective of this design effort has been to provide visual consistency between the two XR applications addressed directly to visitors of cultural heritage sites: **AR Tour Experience** and **3D XR Studio**, while clearly differentiating them as distinct tools. The intention was to create two applications with individual identities, and belonging to the same project "family" at the same time.

Although the harmonisation effort has focused mainly on the visitor-facing tools, the Design Guidelines have been conceived to be applied to the five tools developed within the project. **AR Tour Builder**, **AI 3D Builder**, and **Avatar Builder** may adopt and apply the same visual principles, ensuring that the entire toolbox presents a unified image.

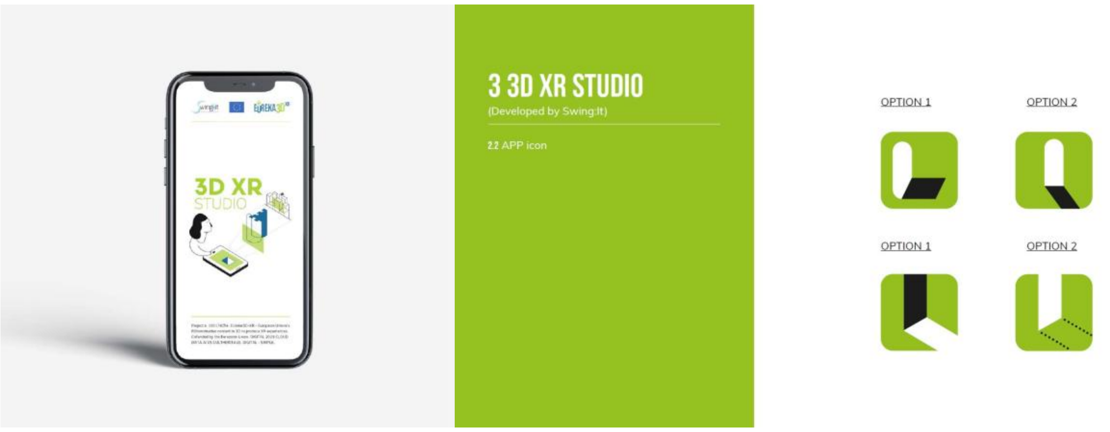
The Apps Design Guidelines define and regulate the following key design elements:

- The **AR Tour Experience** and **3D XR Studio** app icon designs, as well as clear rules for the application of the project logo, EU emblem, Grant Agreement number, and copyright information on the entry screens, ensuring both brand coherence and compliance with EU visibility requirements.
- A harmonised colour palette derived from the project's visual identity and a structured typography hierarchy to ensure visual consistency, readability, and accessibility.
- The style of buttons and common interface icons, alongside recommendations for creating additional icons when needed. Vectorised assets enable adaptation and scalability.
- Points of Interest (POI) icons that remain recognisable across different implementation contexts.
- Other navigation features such as spinners, paginations or complementary banners.
- Accessibility principles, such as sufficient colour contrast, appropriate text sizing, and adequate touch areas.

Overall, the Apps Design Guidelines contribute to reinforce the app's identity as a coherent and user-centred XR toolbox.



Draft proposal for the AR Tour Experience first screen and icons



Draft proposal for the 3D XR Studio first screen and icons

5. USER MANUALS, DOCUMENTATION & DISSEMINATION

From the onset of the EUreka3D-XR project, documentation of capacity building initiatives has a central role, i.e. providing users with support in the form of user manuals for the EUreka3D-XR toolbox, technical and educational documentation on the project's outcomes and broader dissemination activities.

The overall capacity building and dissemination strategy was built on these principles:

1. A standardised, structured and incremental approach for designing training and dissemination materials
2. Connecting technical innovation with real life examples across sectors
3. Open availability and reusability of resources
4. Iteration and feedback collection
5. Multilingual resources

These principles inform the design of the user manuals, documentation and dissemination materials and activities of the EUreka3D-XR project, and help define lessons learned and areas for improvement after the project's lifespan.

These principles are also reflected in the Deliverable D5.1 (*Capacity Building Implementation report*), published in May 2025.

5.1 USER MANUALS AND TOOL DOCUMENTATION

In order to provide standardised and structured user manuals across all five tools which are usable for a wide variety of professionals, the tool documentation is structured in a layered model:

On the complete toolbox: an overview of the available tools is provided

- What is in the toolbox and how do I choose the one fit for my case?
- Links to the tool specific documentation

On each separate tool

1. Quick start: factsheet
2. Step-by-step guides with task based recipes (i.e. How do I place a model on a map in a tour?)
    a. If possible, supplemented with tutorial videos
3. Technical documentation with more advanced information, where relevant and applicable.

This layered approach is aimed to accommodate diverse audiences: curators and archivists with limited technical backgrounds, more advanced digital practitioners, and developers interested in integration or reuse.

Clarity and accessibility of the manuals

- Clear and consistent terminology
- Activating language
- Avoidance of unnecessary technical jargon
- Annotated screenshots and visual cues
- Explicit indication of required versus optional steps

The documentation emphasises task-based workflows and goal-oriented guidance in order to facilitate a sense of progress while minimising user friction. Tool documentation and guidelines are integrated with the use-case scenarios to provide inspiration and facilitate easier adoption.

5.2 Capacity building resources

Beyond tool-specific documentation, both EUreka3D and EUreka3D-XR projects translated the expertise gained within the consortium into capacity building resources for a wide audience by means of:

- Online courses
- Recorded webinars
- On-site training sessions
- Hybrid events, combination of strategic presentations, awareness raising and more concrete demonstrations of the EUreka3D Data Hub and the toolbox
- Editorials and use case scenarios

5.3 Dissemination

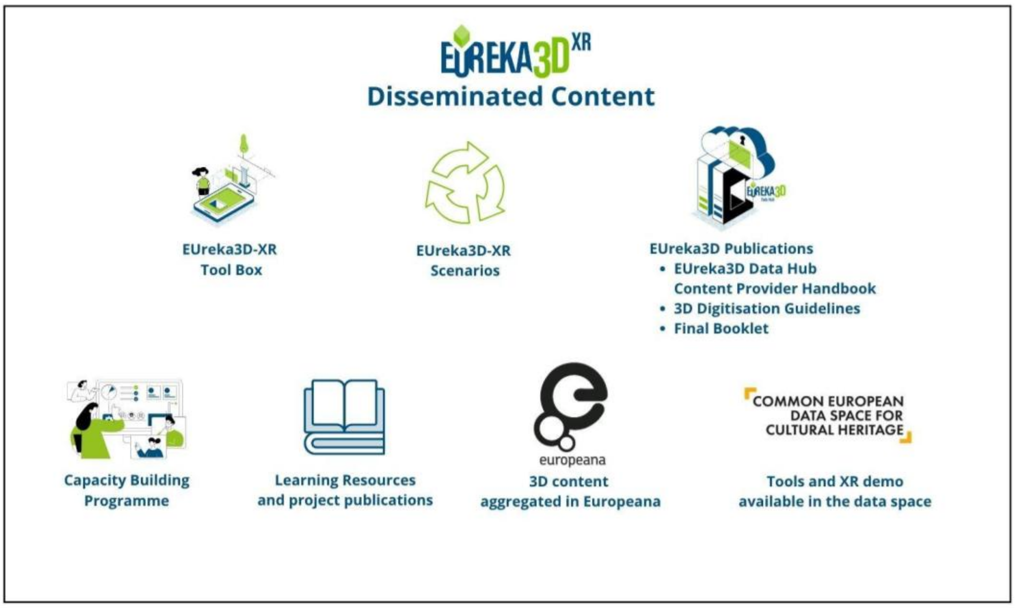
Materials are made accessible in different formats, through online platforms such as the project's website and Zenodo, as free downloadable PDFs and are integrated into established dissemination channels such as the Europeana Academy, the EUreka3D website, the Photoconsortium Educational Portal and the partners' websites focusing on the elements that are of interest for their targets.

The project's overall approach to dissemination has been designed to ensure that its results are understandable and reusable for diverse target audiences, primarily Cultural Heritage professionals. The assessments in this chapter are based on the actions described in Deliverable D4.1 (*Dissemination and exploitation plan*[5]), delivered in July 2025.

By building upon the established channels of the previous EUreka3D project rather than creating new, fragmented platforms, the project has prioritised coherence and continuity. This approach has strengthened brand recognition and facilitated engagement for stakeholders already familiar with the project.

The creation of a Communications, Editorial and Capacity Building Board has ensured consistency of messaging, coordination of dissemination actions across partners and regular monitoring of performance indicators. The Board has worked through structured editorial planning (including the project blog, Europeana editorials, website and newsletter) and alignment with defined KPIs. In addition, the dissemination of multilingual versions of published content has been applied both to Europeana editorials and to the *3D Digitisation Guidelines*, reinforcing inclusivity and accessibility.

[5] EUreka3D-XR. 'D4.1 Dissemination and exploitation plan'. https://eureka3d.eu/wp-content/uploads/2025/07/EUreka3D-XR-D4.1-dissemination-exploitation-plan.pdf



EUreka3D-XR disseminated content

Dissemination materials, including editorials, publications, case studies, videos, newsletters and training resources are produced with target audiences and stakeholders in mind. The project's main goal is to disseminate the results of the EUreka3D-XR pilot activities to diverse target audiences, with a particular focus on the development and usability of the project's toolbox and the derived XR scenarios.

EUreka3D-XR Ecosystem

Clarity and accessibility have been addressed through a structured web presence, a centralised repository of materials (including the Zenodo open access platform), multilingual communication through partners' channels, and GDPR-compliant subscriber management for newsletters. The reuse of existing subscriber bases and social media communities has improved efficiency and outreach. Quantitative KPIs (newsletter reach, website visits, social media followers, event participation and editorial outputs) are regularly reported in progress reports.

Publications represent a pillar of the project's dissemination strategy. The final booklet, to be distributed at the closing event, provides a hands-on and reflective vision of the implementation of the three XR scenarios, documenting lessons learned, methodological insights and practical outcomes. This publication not only contextualises the project's toolbox and results, but also serves as a reusable resource for CHIs embarking on similar digital transformation processes.

The three case studies included in the booklet will also be disseminated separately as standalone open access publications to maximise their reach and reuse potential. Furthermore, the *3D Digitisation Guidelines* have been newly translated and redesigned into five languages (Catalan, Spanish, French, Italian, Dutch and Greek) and will be made available online.

6. User feedback

In the Deliverable D5.1 (*Capacity Building Implementation report),* a chapter was dedicated to gathering feedback from participants of capacity building activities and resources. The goal of the feedback collection is to measure the impact and to refine the content and approach of those activities and resources.

Ideally, feedback is collected before, during and after a capacity building activity and is structured cross-events to draw clear conclusions. During the project so far, feedback collection has been organised in line with the format of the activity, including:

- Focus groups: feedback collection during and/or after the activity
    - Two online sessions with the project's Advisory Board and the EUreka3D-XR consortium;
    - One on-site hands-on workshop with archivists and information professionals from Girona working with the AI 3D Builder
- Measuring impact, satisfaction and areas for improvement in surveys (feedback collection before, during and/or after the activity
    - Hybrid capacity building event in Brussels
    - Online training programme (3 sessions) '*Driving digital transformation in Cultural Heritage Institutions'* in collaboration with International Council on Archives
    - Hybrid demonstration event in Girona

6.1 Lessons learned and areas for improvement

Throughout the first year of the project, the EUreka3D-XR toolbox was presented to the Advisory Board for feedback in two focus groups during different iterative phases of development. Following the release of the scenario prototypes, a dedicated focus group was conducted in Girona (January 2026) to evaluate the AI 3D Builder in a hands-on workshop. As further surveys and focus groups are conducted in the coming months, these initial findings described below will be expanded and refined.

1. **The greatest challenge is adoption of tools and workflows by stakeholders**
    - Move from presentations and demonstration to hands-on activities and tool documentation
    - Feedback consistently indicates that the perception of the usability and possibility for adoption depends heavily on the quality of the documentation and opportunities for training and consultation
2. **Perceived barriers for adoption are mostly structural, not (only) technical (including lack of time and resources, in-house expertise etc.)**
    - Include questions in future surveys on how the tools can better accommodate these barriers
3. **One size does not fit all users**
    - Layered tool documentation: from task-based recipes to technical documentation
    - Pay attention to expectation management for tool users and participation in workshops
    - Existing external tools used in XR-workflows, such as Photopea and Blender, may increase the perceived complexity of the toolbox, as they require additional technical understanding. Consider providing manuals and support for these external tools.
    - Differentiate target audience in capacity building activities and feedback collection
4. **Hybrid and online events have the greatest outreach (sectoral, geographic, skill level) but real-time engagement is low, which limits the impact of the activity and possibilities for adoption by the participants**

- Online training sessions with a pre-selected group of participants show the opposite: high engagements and satisfaction, and a perceived gain in knowledge and skills

5. **Participants value transparency about tool limitations, including functionalities still under development**
    - Communicate that user feedback are taken into account in iterative development of tools, activities and capacity building resources
    - AI-based workflows in the toolbox were raised as a concern by multiple participants

7. CONCLUSION

Quality within the EUreka3D-XR project has been approached in a systemic and transversal way, rather than as an isolated objective. As demonstrated throughout this report, ensuring quality requires coordinated attention to multiple interdependent dimensions: the technical and visual fidelity of 3D content, the robustness and semantic clarity of metadata and paradata, the consistency of infrastructure and deployment environments, the usability and accessibility of tools, and the responsiveness to stakeholder feedback. Together, these dimensions shape the reliability and long-term value of the project's outputs.

The assessment presented in this deliverable confirms that quality considerations have been embedded across the project lifecycle, from data ingestion and harmonisation to tool development, deployment, documentation, and user validation. The close collaboration between CHIs and technology partners has played a central role in aligning technical solutions with curatorial needs and user expectations.

By treating quality as an operational philosophy and continuously reflecting on its implementation, EUreka3D-XR contributes to the development of sustainable, trustworthy, and reusable XR ecosystems for digital cultural heritage. While this deliverable documented how quality has been operationalised within the EUreka3D-XR project, the subsequent Deliverables D3*.7 (Formats and Quality Guidelines Report*) and D3.8 (*Paradata and Sustainability Report*) will translate these experiences into recommendations and guidelines for external audiences and as such support the wider dissemination of the project's approach in achieving quality.