IMPULSE

IMmersive digitisation: uPcycling cULtural heritage towards new reviving StratEgies

Deliverable 1.2:

User Research Report: UX Evaluation of IMPULSE VR Prototype

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(1) D1.2.	*The document describes a comprehensive user research targeted to relevant user groups. Much work has been devoted to the task, with complementary actions that all converge toward similar conclusions. However, the document focuses too much on the "what" and "how" and not enough on the "why". It indeed tends to confuse various levels of analysis, and as a result is not clear enough on the definition of the high level experience goals (e.g. messages that have to be communicated through the experience, how to leverage on the identified CH assets, innovative aspects...) or the difference between the functionalities that will be related to authoring the experiences, to experiencing the digital assets or to animate the online community. Likewise, the document lacks an overall classification of the objectives the VR & multi-user VR experiences can contribute to (e.g. create a memorable historically correct experience, enable the precise manipulation of CH objects, enable the understanding of CH environments, storytelling in a CH context...), and what is lacking in the state of the art to support such objectives. While most of the answers can certainly be found in the numerous exchanges with the user groups, the deliverable has to be updated to clarify both the high level goals and the low level authoring & experiencing functionalities as well as the relationship between both.*	Recommendations implemented. Document revised and supplemented with missing elements by the authors. The whole document was re-submitted for internal evaluation and underwent a quality control process in accordance with the consortium's standard practice. Added/improved content parts: • 5.4 • 5.5 • 5.6 • 5.7 • 6.3.1 • 6.4 • 7.4 • 9 (9.1-9.4) • 10 (10.1-10.7) • 11 Document was organized accordingly.	Completed

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2 Executive summary

This revised version of D1.2 -Report on qualitative and quantitative UX research consolidates multi-method findings from WP1 (Task 1.1.3) and, in line with the EC review, makes explicit the experiential rationale (the "WHY") and its mapping to user tasks and design-oriented requirements (the "WHAT/HOW"). The study triangulated a co-creative UX workshop (Leuven), structured surveys, and semi-structured interviews across the three user groups defined in WP1/D1.1: G1 students, academic teachers and researchers; G2 artists and art-school educators; G3 cultural and creative industries (CCI) professionals.

Design-oriented requirements (WHAT/HOW). To operationalise the above, the deliverable summarises concrete, user-facing needs traceable to tasks and functionalities, including:

clear navigation/orientation in 3D;
basic, reliable object inspection/manipulation (rotate/zoom/compare/annotate);
smooth onboarding and tutorial flows for first-time users;
role-based multi-user interaction (guides/participants/moderation);
annotation with metadata/provenance cues;
measures that widen access (e.g., low-barrier entry paths), with HCI accessibility features recorded as future-facing recommendations;
technical robustness appropriate to pilot-level professional workflows.

These requirements act as a bridge from experiential objectives to the functional areas of the IMPULSE platform and inform WP2's prioritisation.

User-group patterns (G1, G2, G3). Convergent evidence shows:

G1 prioritises clear structure, onboarding, and curricular alignment;
G2 prefers open, expressive and affectively rich formats for creative exploration;
G3 emphasises robustness, interoperability signals and workflow fit.

Common expectations across all groups include interface intuitiveness and a clear sense of value and purpose in use. These patterns inform provisional personas and motivate differentiated intents for authoring, experiencing, and community (MUVE/IMCo) features.

From user goals to functional areas. To avoid conflating analysis levels, D1.2 distinguishes three domains and provides a non-prescriptive traceability from objectives to user tasks and functional areas:

Authoring (scene building, narrative scaffolds, templates, annotations/provenance);
Experiencing (navigation & object interaction, guided modes, measures widening access);

Community MUVE/IMCo (roles & permissions, synchronous/asynchronous sessions, basic communication and safety).

This structure directly answers the EC request to separate authoring, experiencing and community-animation functionalities and to show their relationships to the WHY.

Research background and gaps. A concise, evidence-informed literature synthesis is added to the Introduction, used here to interpret findings. The field indicates strong signals for educational value, narrative engagement and social co-presence, alongside recurrent risks (usability, interoperability, motion sickness, privacy, sustainability). These observations motivate the project's focus on standards/metadata alignment and re-use of existing assets.

Near-term priorities (indicative). Grounded in workshop, survey and interview data, and consistent with the research background, the next iteration should concentrate on three cross-group priorities where feasible:

stable navigation and dependable object inspection;
guided multi-user sessions with clear roles and voice/chat;
in-scene metadata/provenance cues to support trustworthy, reusable narratives.

Positioning of this deliverable. This deliverable is **a reference framework,** not a development blueprint. The IMPULSE platform is not the end goal of WP1; D1.2 consolidates exploratory user research and translates it into indicative requirements and priorities. Final implementation choices and their ordering will be decided in WP2 (Task 2.3) in light of the state of the art, GA objectives and project constraints. Not all user-identified needs can be implemented within current scope, resources or staffing; they are recorded here as research-grounded recommendations to inform rational prioritisation in WP2 and to guide future work in the cultural-heritage domain.

Key words:

user experience, immersive environments, cultural heritage, extended reality, UX research, participatory design, co-creation, user groups, XR, virtual reality, prototype evaluation, interaction design, persona construction, narrative strategies, education and the arts.

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4 Abbreviations and Acronyms

Abbreviation / acronym	Description
AR	Augmented Reality
CCI	Cultural and Creative Industries
CH	Cultural Heritage
D1.2	Deliverable number 1.1 / 1.2
DC	Dublin Core Metadata Standard
DoA	Description of Action
EC	European Commission
ECCCH	European Collaborative Cloud for Cultural Heritage
FIG.	Figure
G1	Group 1
G2	Group 2
G3	Group 3
GLTF	Graphics Library Transmission Format
IIIF	International Image Interoperability Framework
IMCo	MPULSE Community of Practice; shorthand for community and multi-user co-presence features developed within the project (MUVE/IMCo).
JPG	Joint Photographic Experts Group
MUVE/IMCo	Multi-User Virtual Environment integrated with the IMPULSE Community of Practice;
PNG	Portable Network Graphics
SVG	Scalable Vector Graphics
UEQ	User Experience Questionnaire
UX	User Experience
VR	Virtual Reality
WP	Work Package
WP1	Work Package 1: Extended Storytelling Towards Vivid User Experiences
XR	Extended Reality

5 Introduction

5.1 IMPULSE Project

The **IMPULSE Project (IMmersive digitisation: uPcycling cULtural heritage towards new** reviving StratEgies; GA No. 101132704) addresses key challenges in the *interoperability* and *sustainable re-use* of digitised cultural heritage (CH) collections across Europe. It develops inclusive and innovative strategies for engaging with *existing* digital heritage assets rather than performing digitisation itself, through immersive technologies such as XR, VR and MUVE (Multi-User Virtual Environments). The project particularly focuses on educational, artistic, and creative applications of immersive cultural heritage.

Building on the European Commission's vision for the European Collaborative Cloud for Cultural Heritage (ECCCH) and related data spaces, IMPULSE pursues four strategic objectives defined in the Grant Agreement:

Simplifying and aligning standards and workflows for immersive CH;
Enabling meaningful re-use of digitised collections;
Ensuring legal, ethical and IPR compliance in new digital contexts;
Supporting inclusive access and co-creation across diverse communities and the Cultural and Creative Industries (CCI).

The project integrates methodologies from information science, heritage studies, the arts, digital design, and the social sciences into a shared framework for **immersive storytelling and co-creation**. It engages artists, educators and creative professionals in the reinterpretation of cultural heritage, contributing to **user inclusion**, **narrative diversity**, and **hybrid digital practices**.

Methodological positioning

IMPULSE follows a two-track, **mixed methodology**. First, it develops and iteratively refines an authoring platform that enables the creation of multi-user virtual environments (MUVEs). Second, it designs and produces MUVEs **exploratorily and participatorily** with users. This dual approach combines conceptual and empirical work with technical implementation but also defines the project's boundaries.

WP1 identifies user needs and experiential goals (Deliverables D1.1-D1.3), establishing the empirical and methodological foundation.
WP2 translates these insights into concrete technological and prototypical functionalities.

In this sense, WP1 defines *what should be experienced and why*, while WP2 defines *what can be built and how* within the scope and technical feasibility of the project.

Relation to other Work Packages

This deliverable reports specifically on Task 1.1.3 within WP1.1. Its results inform:

WP2, implementing immersive and multi-user technologies;
WP3, developing standards, metadata and paradata frameworks;
WP4, addressing legal, ethical and IPR issues; and
WP5, focused on dissemination, community-building (IMCo) and exploitation.

In this way, IMPULSE contributes not only through exploratory platform development but more importantly by generating empirical evidence and user-grounded guidelines for interoperable, human-centred immersive CH infrastructures.

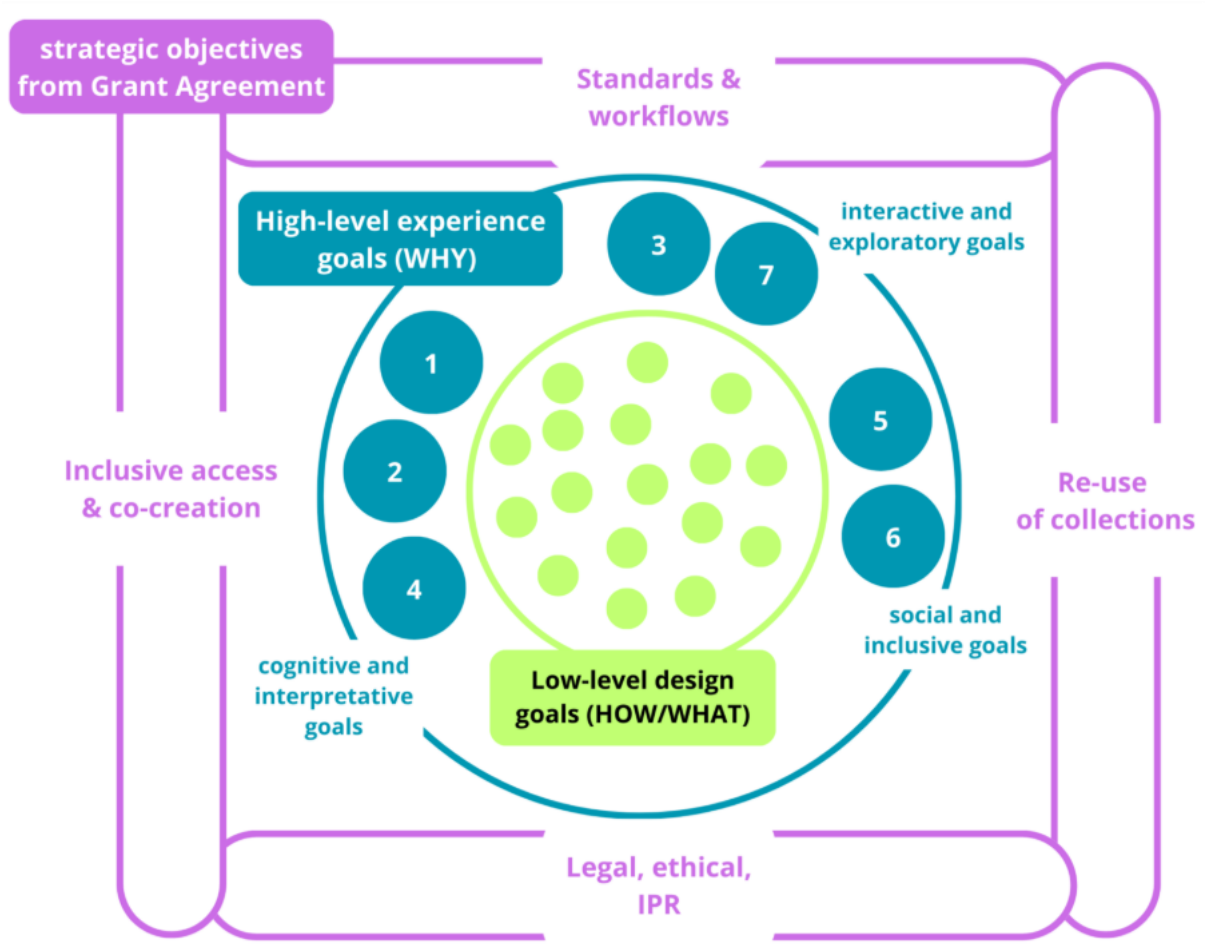
Conceptual structure

Figure 1 summarises the conceptual logic of the project. It distinguishes three interrelated layers:

strategic objectives, as defined in the Grant Agreement, framing systemic and institutional aims;
experiential goals, derived from user research, clarifying *why* immersive and multi-user VR is valuable in CH contexts;
design-oriented requirements, outlining *how* these experiences can be translated into functional and user-facing features.

These layers form a **reciprocal ecosystem**: strategic objectives provide the enabling conditions; experiential goals give cultural and user-centred meaning; and design requirements connect both with feasible implementation paths in WP2.

Fig.1. The conceptual structure of the IMPULSE framework



The diagram visualises the relationship between three interconnected layers of objectives:

- **strategic objectives (in pink)**, as defined in the Grant Agreement, which articulate what the project must achieve at a systemic and institutional level;
- **high-level experience goals (in teal)**, derived from user research, which explain why immersive and multi-user VR is needed in the CH domain and define the intended qualities of experience;
- **low-level design goals (in light green)**, identified through the study, which indicate how these experiential aims can be translated into concrete platform functionalities and user-facing features.

This diagram does not signify a shift in methodological approach; rather, it offers a visual summary and interpretative complement in the context of the EC's observations. This approach is in alignment with the methodology outlined in D1.1 and the Grant Agreement. This does not imply a change in the scope of research during the course

of the project; rather, it signifies that the results are presented in a more transparent manner and in alignment with the EC's requirements.

Clustering of experiential goals

User research groups experiential goals into three interdependent clusters:

interpretative and narrative - understanding cultural contexts, meaning-making, storytelling and reflection.
interactive and exploratory - engaging with digital heritage objects, inspecting and manipulating assets, ensuring re-use and interoperability.
social and inclusive - enabling co-presence, collaboration, and widening access across diverse audiences.

These clusters reinforce one another: interpretative meaning-making depends on interaction; interaction gains value through collaboration; and inclusivity ensures all users can meaningfully participate.

They together represent the **experiential rationale** for IMPULSE and will inform WP2's prioritisation of functionalities.

Implementation scope

This deliverable defines **user-centred experiential directions**, not prescriptive development tasks.

Implementation priorities will be determined within WP2 (Task 2.3) based on:

technological feasibility and current state of the art,
project objectives, and
temporal and budgetary constraints.

The outcomes of this study provide a foundation for refinement, verification, and potential implementation of selected functionalities in subsequent WPs, as well as for future research and development beyond the current project scope.

5.2 Objectives of the Work Package 1

Work Package 1 (WP1), entitled *Extended Storytelling Towards Vivid User Experiences*, is one of the foundational modules of the IMPULSE project. Its overarching goal is to conceptualise, develop, and empirically validate new modes of storytelling in immersive environments based on user needs, narrative diversity, and technological affordances.

WP1 seeks to:

- identify and define the information needs and behaviours of selected user groups interacting with immersive cultural content,
- investigate affective, cognitive, and social dimensions of XR-based user experiences,
- support the design of educational and artistic applications using extended reality (XR),
- and produce guidance for narrative structures and interaction strategies that are accessible, inclusive, and adaptable to different audiences and contexts.

To achieve these goals, WP1 includes the **design of a comprehensive research methodology** (developed in D1.1), followed by **empirical UX research** (documented in D1.2), and culminating in behavioural diagnostics and persona construction (in D1.3 and beyond). The findings from WP1 are directly integrated into the technical development of the prototype platform in WP2, ensuring continuity between conceptual design, user engagement, and implementation.

5.3 Objectives of the Task 1.1

Task 1.1 (*UX Research*) is the core empirical component of WP1 and is led by the Jagiellonian University in collaboration with project partners from Belgium, Italy, Greece, Germany and Malta. It consists of seven interrelated subtasks (1.1.1-1.1.7), spanning the entire duration of the project (months 1-36). These include literature review and methodological design (1.1.1-1.1.2), empirical user research (1.1.3-1.1.5), final usability testing (1.1.6), and educational dissemination activities (1.1.7).

Deliverable D1.2 corresponds directly to **Task 1.1.3:** User study: preliminary research before developing prototypes. This subtask is focused on identifying:

- users' information requirements, expectations, and behavioural patterns.
- digital and cultural competencies (e.g., knowledge of software, instruments, interpretative frameworks).
- motivational and emotional factors involved in immersive engagement.

According to the Grant Agreement and WP1 roadmap, Task 1.1.3 is scheduled for months 7-15 of the project, serving as a bridge between conceptual methodology development (1.1.1-1.1.2) and prototype refinement (1.1.4-1.1.5). Its function is to collect and analyse empirical data from key user groups before the first complete version of the prototype is finalised.

The research includes both quantitative (survey-based) and qualitative (interview, observation, workshop) components and is conducted among the three primary user groups identified in WP1 and D1.1:

- Group 1 (G1) -This group comprises students, university educators, and researchers, representing a broad range of expertise with immersive technologies, including VR. It encompasses both novice and expert users who engage with XR technologies primarily in academic settings, for research purposes, and in educational contexts. Members of G1 are key in testing the educational potential of the VR system and exploring its application in both teaching and academic research across various disciplines.

- Group 2 (G2) -This group consists of artists, art educators, and creative practitioners, with varying levels of engagement with digital tools. G2 members are primarily focused on exploring the creative possibilities of VR, using the platform for artistic expression, innovative narrative forms, and experimental applications in the visual and performing arts.

- Group 3 (G3) -This group includes professionals from the Cultural and Creative Industries (CCI), such as curators, game designers, multimedia developers, and cultural heritage specialists. G3 participants engage with immersive technologies from a professional perspective, aiming to integrate VR into real-world workflows for content creation, curation, and cultural heritage management.

The results of Task 1.1.3 feed directly into the design, content curation, and functional development of the immersive prototype in WP2. By mapping user needs and practices, the task helps ensure that future technological solutions are inclusive, responsive, and grounded in real-world contexts of digital heritage interaction.

5.4 Background and Rationale

This deliverable, D1.2 -Report on qualitative and quantitative UX research, presents the results of Task 1.1.3 *User study: preliminary research before developing prototypes*, conducted between project months 7 and 15 under Work Package 1 (WP1) -Extended Storytelling Towards Vivid User Experiences. The task was led by the Jagiellonian University. It should be highlighted that deliverable reports specifically on Task 1.1.3 within WP1.1. Other tasks in WP1 (1.2 and 1.3) pursue distinct objectives and are therefore outside the scope of D1.2.

WP1 provides the empirical and methodological foundation of IMPULSE: it identifies real user needs, behaviours and expectations to guide the design of immersive narrative strategies and interaction models. In this way, WP1 ensures that subsequent

developments in WP2 (technical prototyping), WP3 (standards and metadata), WP4 (legal/IPR) and WP5 (dissemination and community building) remain grounded in a human-centred, inclusive framework.

Task 1.1.3 represents the first empirical investigation in this process. Its objectives were to explore:

- user information needs, behavioural patterns and digital competences;
- motivational and affective dimensions of immersion;
- experiential qualities of interaction with early-stage prototypes.

To achieve this, a **triangulated research design** was implemented, combining:

- a co-creative UX workshop (Leuven) with an interactive prototype,
- quantitative online surveys with groups G1 and G2,
- semi-structured interviews with users and experts across G1-G3.

The study engaged the three target groups defined in D1.1: G1 (students, academic teachers, researchers), G2 (artists and art school educators), and G3 (cultural and creative industries professionals). Not all subgroups were involved in every phase; sampling was adapted to the focus of each activity.

By capturing perspectives from these distinct but complementary communities, the research generates critical insights into how immersive cultural heritage experiences can support education (G1), creativity (G2), and professional innovation (G3). The resulting evidence directly informs the design of the IMPULSE platform, contributes to persona refinement in D1.3, and provides a baseline for behavioural diagnostics and cross-WP integration.

5.5 Updated research context and conceptual foundations for IMPULSE

This section provides an updated overview of the research context relevant to the interpretation of the IMPULSE user-experience study. It does not constitute a full state-of-the-art review but rather a targeted synthesis of the most recent literature and empirical findings that were current at the time of analysing the results. The aim is to situate the qualitative and quantitative evidence within the broader academic and technological landscape of immersive and multi-user virtual environments (VR, XR, MUVE) for cultural heritage, identifying key trends, good practices, and persistent challenges that inform the project's priorities and limitations.

It should be noted that further information regarding the current state of research on MUVE technologies, processes, formats, impediments and best practices can be found

in Deliverable 2.1. In addition, research on methodologies for studying VR users is included in Deliverable 1.1.

Positive trends

Research highlights several domains where VR and MUVE add clear value to CH:

- **Education and learning.** VR storytelling and gamification promote active learning, agency and knowledge retention. As an example, previous studies have shown that interactive storytelling fosters active learning and user agency (Petousi et al., 2022), gamification enhances engagement and concentration in museum VR (Sangamuang et al., 2025), and gamification leads to better content retention (Yolthasart et al., 2024).
- **Emotional engagement and empathy.** Multisensory XR increases affective immersion and fosters historical empathy. As previous research illustrates, multisensory experiences intensify engagement (Boboc et al., 2024), XR contributes to stronger emotional immersion (Spadoni et al., 2023), and interactivity in the metaverse enhances the perception and experience of heritage (Alsuwaidi & Almazrooei, 2025).
- **Authenticity and credibility.** Photogrammetry, 3D reconstruction and high-fidelity rendering enhance trust and educational value. Building on this, Bekele & Champion (2019) point out that accurate 3D models support learning through credibility. Rodriguez-Garcia et al. (2024) highlight that photogrammetry and 3D reconstruction enhance authenticity and credibility by grounding models in archaeological evidence. Moreover, they note that high-fidelity rendering increases realism, which strengthens user trust and boosts the educational value of virtual heritage experiences.
- **Innovation and exploration.** Immersive reconstructions allow access to sites, narratives and artefacts otherwise unavailable, extending museum experiences. Shehade & Stylianou-Lambert (2020) indicated that VR in museums enhances curatorial possibilities. Lee et al. (2020) showed that VR strengthens immersion and can “transport” users into the past.
- **Community and participation.** Multi-user VR fosters co-creation, collaborative interpretation and shared narratives. For example, Dreksler and Bacha (2025) show that multi-user immersive VR (MIVR) tools support the democratization of the design process, enabling equal contributions from both designers and individuals without formal training, thereby fostering co-creation and participation.
- **Accessibility and inclusion.** User-centred design and adaptive interfaces enable wider participation, including for people with disabilities. For example, Agulló et al. (2019) examined methods of presenting subtitles in VR (e.g., fixed position versus always-visible captions) as well as user guiding techniques, such as arrows or automatic positioning, to maintain immersion and improve content readability in virtual environments.

Alsuwaidi & Almazrooei (2025) emphasized the role of the metaverse in expanding accessibility.

- **Sustainability.** Virtual museums and online tours can reduce the ecological footprint of mass tourism and support environmental awareness. For example, Zhang and Huang (2025) analyse how tourism based on virtual reality (VR) affects psychological well-being and the sense of meaning in life. At the same time, they emphasize that VR represents an innovative tool for reducing the ecological footprint of traditional travel, which aligns with efforts toward sustainable tourism. However, this standpoint should still be balanced against the energy costs of creating and maintaining VR infrastructures.

Risks and barriers

Despite these advances, the literature also highlights persistent challenges:

- **Usability and UX gaps.** Non-standardised interaction models, technical instability and poor onboarding frustrate users (Shikhri et al., 2023; Komianos, 2024).
- **Cognitive overload and superficiality.** Excessive immersion or gamification can distract from critical reflection and content learning (Besoain et al., 2022).
- **Health and safety risks.** VR sickness, eye strain and disorientation remain common (Biswas, Mukherjee, Bhattacharya, 2024; Chang, Kim, Yoo, 2020; Msweli, Phahlane, 2025).
- **Technological barriers.** High equipment costs, limited interoperability and digital decay threaten long-term accessibility (Innocente et al., 2023).
- **Privacy and ethics.** Tracking of movement, gaze and voice raises concerns about surveillance and data protection (Giaretta, 2025; Miller et al., 2020).

Equity and access. Hardware costs and digital literacy gaps risk excluding certain groups, especially older or less technologically confident users (Dick, 2021).

Relevance for the IMPULSE Framework

The updated research context confirms that immersive and multi-user environments hold significant potential for enhancing learning, affective engagement, and collaborative participation in the cultural heritage domain. At the same time, these benefits can only be realised sustainably if persistent challenges, such as the absence of shared standards, limited interoperability, uneven accessibility, and emerging ethical or privacy concerns are effectively addressed. These insights substantiate the rationale and orientation of IMPULSE, which seeks to simplify standards, enable the re-use of digitised cultural assets, foster inclusivity, and promote sustainable, human-centred practices across the European cultural heritage ecosystem.

5.6 User Experience Framework: Goals and Design Scope

This deliverable provides a clear articulation of the 'WHY' of IMPULSE -the overarching experiential objectives and their operational translation into design goals that immersive cultural heritage technologies aim to support. These goals define the value proposition of IMPULSE, guiding the design of functionalities and evaluation metrics, and providing the logic for change. They were not only identified in the literature review but also strongly evidenced in user research; for example, students emphasised memorability and learning benefits (see Section 8.1, 8.2). It should also be noted that the high-and low-level goals presented here are not abstract design assumptions but were directly distilled from the evidence collected through the Leuven workshop, surveys, and interviews reported in D1.2. User-identified needs -such as difficulties in navigation, demand for role-based collaboration, or requests for intuitive object manipulation -were systematically translated into functional objectives. This ensures that the platform's architecture remains firmly grounded in empirical user research.

Experience goals derived from user research (high-level experience goals)

It should be emphasised that the indicated experience and operational goals were determined on the basis of qualitative and quantitative analysis of various user research methods that have been implemented in the IMPULSE project to date. However, the analysis of the selection of functionalities determined by users during the research belongs to WP2 and depends on the scope of tasks, budget, time, equipment and human resources.

The indicated experience goals by users are:

Embodied experience of cultural heritage environments and contexts.
Enable users to orient themselves and meaningfully situate cultural heritage within its spatial, historical, and cultural frames, supporting education and interpretation -without implying professional GIS or architectural simulation capabilities.

Creating memorable and trustworthy encounters.
Foster immersive experiences that promote engagement, plausibility, and retention of information, contributing to cultural literacy and user trust -without claiming full historiographic accuracy.

Inspection and manipulation of CH objects.
Provide intuitive tools for examining and engaging with digital artefacts (e.g., rotate, zoom, compare, annotate) to enhance interpretation -without requiring professional-grade measurement or modelling workflows.

Narrative structuring and storytelling.
Support the organisation of experiences through spatial sequencing and multimodal cues. Optional narrative layers (e.g., educator or curator

notes) may enrich understanding, but complex scripted storytelling systems remain outside the project scope.

Social co-presence and co-creation (MUVE).
Enable synchronous and asynchronous participation, collaboration, and community building within shared immersive environments. This also encourages interdisciplinary interaction between artists, educators, and professionals (G2/G3), fostering hybrid cultural and creative practices.

Accessibility and inclusivity.
Promote broader access to cultural heritage by reducing barriers related to geography, cost, and digital literacy, in line with the Grant Agreement. HCI-style accessibility functions (e.g., captions, alternative inputs) are recognised as user recommendations for future development rather than project deliverables.

Sustainability and re-use of digital CH assets.
Support the long-term re-use and preservation of cultural heritage content through alignment with metadata, standards, and provenance practices (WP3). This refers to the sustainability of digital assets, not to ecological sustainability.

Interpretive framework: Linking user research and platform development
This framework outlines how the insights from WP1 user research inform and interact with the technical and creative developments of WP2-WP5. It does not reformulate project objectives or introduce new evaluation criteria; rather, it serves as an **interpretive bridge** between exploratory evidence and design implementation.

The framework identifies four key linkages:

Inputs: Pre-existing digitised cultural heritage collections, simplified standards and metadata frameworks (WP3), legal and ethical frameworks (WP4), and mechanisms for community engagement (WP5).

Activities: Participatory user research (WP1), exploratory prototyping and iterative testing of immersive environments (WP2).

Outputs: Functional prototypes of authoring, experiencing, and community environments that demonstrate feasible pathways for user engagement.

Intended outcomes: Strengthened creative participation, educational value, and professional experimentation within immersive cultural heritage contexts. These are intended directions rather than mandatory deliverables.

By situating user evidence and functional prototypes within this broader interpretive chain, the framework clarifies how IMPULSE contributes to exploratory pathways for accessing, understanding, and re-using cultural heritage in line with European collaborative initiatives such as the ECCCH.

Operational design orientations (Low-level goals)

To translate the experiential goals into feasible design directions, the following orientations outline the types of interaction and functionality that *could* be supported by the IMPULSE platform. These orientations are indicative rather than prescriptive and will be further prioritised and specified in WP2 (Task 2.3), according to technical feasibility, available resources, and project scope.

The users' indicated goals are:

Ease of navigation and spatial orientation -provide basic aids for moving and locating oneself within a 3D environment (e.g., teleportation, simple minimaps, guided tours, or visual highlights).
Intent: reduce disorientation and support meaningful exploration of cultural heritage spaces.

Object interaction and examination -allow intuitive manipulation of heritage objects (e.g., rotation, zoom, annotation, simple comparison). Where possible, these interactions should connect to basic metadata or paradata, supporting interpretive depth without implying professional measurement tools.

Onboarding and learning flow -provide a smooth learning curve through simple tutorials or scaffolded guidance for first-time users, to encourage accessibility and engagement.

Role-based multi-user interaction -enable differentiated participation (e.g., guide/participant, teacher/student, curator/visitor, artist/collaborator) and support synchronous and asynchronous collaboration.

Narrative structuring and sequencing -allow creators to structure experiences spatially and temporally (e.g., through simple sequencing, triggers, or spatial storytelling). More complex, scripted story engines remain outside the current project's technical scope.

Basic accessibility affordances -support fundamental options such as captions, audio narration, or adaptable controls to accommodate diverse users. Advanced or professional-grade accessibility systems are acknowledged as recommendations for future projects rather than deliverables of IMPULSE.

Robustness and interoperability -ensure stable performance for multi-user interaction, alignment with relevant CH metadata and paradata standards (as defined in WP3), and technical scalability for professional workflows where feasible.

These operational orientations form a bridge between the high-level experiential aims (the *why*) and the functional architecture of the authoring, experiencing, and community

environments developed in WP2. They represent user-informed directions for prioritisation rather than fixed requirements.

Scope Clarifications per Goal

This section further develops the articulation of the experiential "WHY," situating the high-level experience goals (see §5.6) within the methodological and practical boundaries of the project.

The clarifications serve to align expectations between user research (WP1) and platform development (WP2), making explicit what IMPULSE *intends* to support experientially, rather than what it *commits* to implement technically.

Each goal is therefore accompanied by:

- **a clarification statement,** explaining its intended meaning and realistic scope within the IMPULSE framework; and
- **an indicative operational orientatio**n, outlining potential ways in which the goal could be reflected in platform features or environments, depending on WP2's technical feasibility assessment (Task 2.3).

This interpretive structure ensures transparency: it communicates the platform's purpose as an *exploratory and co-creative environment* that supports learning, storytelling, and collaborative engagement with cultural heritage, while acknowledging the project's constraints in terms of time, budget, and technological maturity.

Decisions regarding the technical feasibility and prioritisation of any specific functionality will be taken by WP2 and recorded in its deliverables. In this sense, the clarifications and orientations below should be read as **conceptual bridges** between user experience goals and design development, not as implementation requirements.

Table 1 summarises this relationship by linking:

the high-level experiential intentions (WHY),
their interpretive clarifications (Scope), and
indicative operational orientations (WHAT/HOW).

Together, they illustrate how IMPULSE balances ambition with feasibility -fostering exploratory engagement, learning, and creative re-use of cultural heritage -while recognising that advanced professional functionalities (e.g., GIS-level modelling, CAD-grade inspection, or automated assessment) remain beyond the project's current scope.

Table 1. Experience goals, scope clarifications, and corresponding design intents

Experience goal (WHY)	Clarification (scope statement)	Operational design intents (HOW/WHAT)
Embodied experience of CH virtual environments and contexts	The platform supports exploratory and narrative engagement with cultural heritage settings. It is intended to enable orientation, movement, and contextual understanding rather than professional-grade spatial simulation or GIS-based reconstruction.	-basic navigation and orientation in 3D environments -contextual storytelling through spatial cues and annotations
Memorable and trustworthy encounters	The focus is on fostering engagement, plausibility, and credibility in immersive experiences. The platform does not aim to reconstruct history with full scholarly accuracy but to support historically and culturally plausible narratives that enhance user trust and comprehension.	-narrative scaffolding and guidance -multimedia integration (text, audio, simple visuals or animations) to support immersion and recall
Inspection and manipulation of CH objects	The platform enables intuitive exploration of 3D heritage artefacts but is not designed for detailed measurement or CAD-level modelling. The emphasis is on learning and interpretation through manipulation.	-rotate, zoom, and compare objects -metadata and paradata overlays providing contextual and provenance information
Narrative-driven storytelling	The platform supports the creation of structured and spatially anchored narratives through object placement and sequencing. It is not a professional storytelling engine but allows users to arrange content into meaningful narrative flows.	-placement of objects and narrative cues (e.g. text panels, 3D symbols) -optional co-narration in guided or collaborative sessions
Social co-presence and co-creation (MUVE/IMCo)	The platform enables synchronous and asynchronous collaboration through shared sessions, defined roles, and communication tools. Large-scale MMO or complex world-building functions are beyond scope.	-role-based participation (guide, participant, observer) -real-time interaction and persistence of shared scenes
Accessibility and inclusivity	The system supports inclusive participation through accessible interaction modes and alternative access pathways (e.g. desktop VR). It complements but does not replicate specialist accessibility technologies.	-multiple device options (desktop VR, HMD) -adjustable interface elements (font, contrast, captions) for basic inclusivity
Sustainability and re-use of digital assets	Sustainability refers to long-term digital re-use and interoperability rather than environmental impact. The platform supports integration with external repositories and metadata frameworks but is not a full archival system.	-export/import of scene packages -provenance and paradata capture

		-alignment with interoperable metadata standards (WP3)

The reference to the mapping between the example goals and the actual functionalities indicated during the WP1 studies is provided in Section 8.5.

5.7 Scope and Purpose of this Deliverable

Deliverable D1.2 -*Report on qualitative and quantitative UX research* consolidates the empirical outcomes of Work Package 1 and translates them into design-oriented insights. It bridges conceptual goals (WHY) with user-derived functional expectations (WHAT/HOW) and provides the evidence base for subsequent development in WP2-WP5.

Building on D1.1, which defined the conceptual framework, user groups and methodological approach, this report presents the first comprehensive dataset on how diverse user communities perceive and engage with immersive cultural heritage content. In doing so, it links user experience goals (Section 5.6) with functional recommendations (Sections 8-9), offering a coherent foundation for implementation and validation in later stages of the project.

The scope of D1.2 includes:

- **methodology:** overview of research design, instruments, and ethical considerations.
- **empirical results:** findings from participatory workshops, surveys, and interviews.
- **synthesis:** integration of qualitative and quantitative insights across user groups.
- **design implications:** evidence-based recommendations for interaction, narrative design, inclusivity, and technical feasibility.

The purpose of this deliverable is to document user perspectives and behaviours in early immersive environments and to establish a clear traceability from experiential aims to design priorities. It should be read as an **evidence-based interpretive framework**, not as a prescriptive list of features to be implemented.

D1.2 therefore clarifies how the user research conducted within WP1 informs subsequent stages of the IMPULSE process: guiding WP2 in prioritising development, aligning with WP3 on standards and interoperability, and contributing to WP4-WP5 on ethical, legal, and community dimensions. The deliverable reflects the project's scope as a **proof of concept and exploratory platform**, rather than a fully featured VR system, recognising that implementation choices must balance ambition with technical feasibility and available resources.

6 User Groups and Personas

6.1 Definition and Justification of User Groups

The user research conducted within Task 1.1.3 of the IMPULSE project builds on a structured segmentation of user groups established in WP1 and elaborated in Deliverable D1.1. The rationale for this segmentation is to ensure that the development of immersive digital heritage prototypes is informed by the diverse experiences, needs, and expectations of real users, representing a wide range of educational, artistic, and professional contexts (D1.1, pp. 9-11).

Three main user groups were defined and selected for focused empirical investigation:

- **Group 1 (G1): Students, Academic Teachers, and Researchers.**

This group includes university students, academic teachers, and researchers, representing a range of digital literacy levels and familiarity with immersive technologies. They were selected to test educational use cases and explore user needs in both formal and informal learning environments.

- **Group 2 (G2): Artists and Art School Teachers.**

This group comprises practitioners and educators engaged in the arts, with particular attention to those who work with visual, performative, and interpretive approaches. Their perspective is crucial for validating the artistic relevance and expressive affordances of immersive cultural narratives.

- **Group 3 (G3): Cultural and Creative Industries (CCI) Professionals.**

This group includes curators, digital designers, developers, and other professionals operating at the intersection of heritage, technology, and innovation. Their feedback is key for ensuring that the prototype can be adapted to real-world production environments and creative workflows (D1.1, pp. 9-12).

This tripartite segmentation reflects the project's commitment to inclusivity, sectoral relevance, and co-creation, and enables comparative analysis across user types.

6.2 Key Characteristics

The three user groups identified for the UX research in WP1 differ substantially in terms of their digital competences, usage contexts, and experiential expectations. These differences were initially hypothesised during the preparatory work in WP1 and elaborated in Deliverable D1.1, which provided both the theoretical rationale

and the methodological structure for their exploration (Krakowska et al., 2024, pp. 9-12). They guided the development of research instruments and the interpretation of findings across tasks in WP1.

6.2.1 Information and Digital Literacy.

- G1 (Students and Educators) shows a heterogeneous profile with respect to digital fluency. While some students, especially those in creative disciplines are digitally competent and curious about immersive technologies, others require clear structure and conceptual scaffolding. Academic teachers tend to emphasise usability and educational transparency in immersive content design (Krakowska et al., 2024, pp. 13, 17).
- G2 (Artists and Art School Teachers) generally exhibits high visual and aesthetic literacy, yet their familiarity with immersive and interactive digital systems varies. Many are open to exploratory and speculative approaches, favouring experimentation with content and format. However, for some members of this group, immersive systems represent novel and potentially challenging environments (Krakowska et al., 2024, pp. 13-14, 19).
- G3 (CCI Professionals) is typically characterised by high functional digital literacy. Members of this group including curators, designers, and developers are often well-versed in XR, 3D environments, or digital platforms used in heritage and creative sectors. Their expectations are strongly shaped by professional standards, productivity demands, and integration with existing workflows (Krakowska et al., 2024, pp. 19-21).

6.2.2 Expectations for Digital Heritage.

- G1 values immersive content that is clearly structured, contextualised, and educationally meaningful. Navigation ease and access to supporting information are seen as essential for effective learning engagement (Krakowska et al., 2024, pp. 17, 20).
- G2 expects openness to interpretation, symbolic richness, and opportunities for reappropriation and aesthetic expression. Multimodality and creative affordances are key to maintaining engagement (Krakowska et al., 2024, pp. 14, 21).
- G3 prioritises technical robustness, modularity, and adaptability. Systems should enable efficient content manipulation, exportability, and usability in applied creative contexts (Krakowska et al., 2024, pp. 21-22).

6.2.3 Narrative, Affective, Aesthetic Preferences.

- G1 favours immersive experiences that combine clear narrative trajectories with affective resonance, especially where the content addresses social, historical, or ethical dimensions in culturally situated ways (Krakowska et al., 2024, p. 28).

- G2 engages more easily with open-ended, ambiguous, and affectively rich storytelling formats. Artistic users prefer interfaces and content structures that stimulate the senses, allow freedom of interpretation, and support embodied interaction (Krakowska et al., 2024, pp. 28-29).
- G3 is generally drawn to task-oriented, customisable, and scalable narratives. The emphasis is placed on clarity, control, and alignment with user goals such as exhibition development, audience outreach, or commercial production (Krakowska et al., 2024, p. 29).

These insights formed the conceptual backdrop for the design of surveys, interview guides, and co-creation workshop scenarios. They also support the synthesis of results across user groups, discussed in Section 6.

6.3 Provisional Personas

As part of the interpretative synthesis of user characteristics and early empirical insights, a series of provisional user personas was constructed to represent salient behavioural patterns, motivational profiles, and experiential expectations within each of the three main user groups identified in WP1. These personas are integral to supporting the iterative design process, enhancing the understanding of user needs, and guiding the adaptation of immersive narratives and interaction models throughout the project. By embedding user personas into the design workflow, the project can better align with user preferences and requirements, ultimately leading to a more user-centred approach to immersive technology development. These personas are crucial not only for visualising user characteristics but also for facilitating the targeted development of the immersive environment. They allow designers to make informed decisions about the customisation and personalisation features, as well as to optimise user engagement and interaction quality within the immersive platform. This process enables the creation of a more tailored immersive environment that directly addresses the needs and preferences of different user groups. For instance, G1 may require more structured, pedagogical features; G2 may seek more freedom for expressive interaction and narrative development; and G3 may prioritise tools for curation, metadata integration, and interpretive frameworks. The iterative refinement of personas based on ongoing data collection allows the platform to evolve and be better prepared for future testing phases, ensuring that the system remains flexible and responsive to users' changing needs. Therefore, the continuous development of personas, combined with empirical data, ensures that the immersive environment is dynamic and adaptable, and that the platform can meet both current and future user demands.

While the personas presented here are based on a combination of desk research, literature analysis, and early-stage empirical data (as described in Sections 5 and 6.2), they remain provisional and will undergo further refinement as more qualitative interviews and behavioural diagnostics are integrated during Task 1.1.5. This refinement

ensures that the personas evolve in alignment with actual user feedback and performance metrics. Each persona reflects core attributes observed across user profiles: digital and information literacy, experiential orientation, content and interaction preferences, and attitudinal dispositions toward immersive technologies and digital cultural heritage. This multi-dimensional approach ensures that the personas are holistic and contextually grounded, serving as a practical tool for guiding the development of meaningful and inclusive user experiences in the immersive environment.

Persona 1: "Curious Synthesiser" (G1 -Student, Academic Teacher, or Researcher).

- Background: undergraduate student in humanities with some prior exposure to digital museums and AR/VR in education. Can also represent academic teachers or researchers in the same field.
- Digital competence: moderate. Comfortable using digital platforms but lacks experience with immersive systems.
- Motivations: Seeking engaging, accessible, and personally meaningful content that bridges academic learning with contemporary cultural concerns.
- Behavioural traits: needs structured navigation and clear guidance; responds positively to emotionally resonant content and contextual explanation.
- Pain points: overwhelmed by unstructured interfaces; unsure how to "read" immersive spaces.

Persona 2: "Structured Facilitator" (G1 -Educator)

- Background: senior lecturer with strong interest in integrating cultural heritage into course material.
- Digital competence: high in instructional platforms, low in immersive media.
- Motivations: needs content to be pedagogically grounded, adaptable to learning objectives, and accessible to students with varied backgrounds.
- Behavioural traits: analytical, outcome-oriented, values interpretative clarity and credibility.
- Pain points: distrusts over-stylised interfaces; concerned about student disorientation or cognitive overload.

Persona 3: "Reflective Performer" (G2 -Artist or Educator, Art Teacher).

- Background: independent performance artist and part-time art school instructor. While this persona combines both artists and educators, it is based on the premise that many art school educators also actively engage in creative practices, merging both roles within the same professional identity.
- Digital competence: variable; high aesthetic literacy but limited experience with XR tools.
- Motivations: seeks inspiration, emotional depth, and symbolic openness in immersive environments; views heritage as a medium for artistic transformation.

- Behavioural traits: embraces ambiguity; prefers poetic and non-linear experiences.
- Pain points: frustrated by didactic content; prefers exploration to instruction.

Persona 4: "Strategic Integrator" (G3 -CCI Professional).

- Background: digital curator at a mid-sized design studio developing museum installations and AR applications.
- Digital competence: very high; works daily with interactive platforms and immersive media.
- Motivations: looking for tools that allow creative re-use of content, technical stability, and integration into production pipelines.
- Behavioural traits: pragmatic, efficiency-driven, interested in functionality and scalability.
- Pain points: limited tolerance for experimentation if not aligned with project goals; seeks granular control and reliability.

These personas serve as conceptual bridges between raw user data and actionable design requirements. They offer a humanised synthesis of the user landscape explored in WP1 and will be further refined during the upcoming work in Task 1.1.5 and usability validation in WP2 and WP3.

6.3.1 Comparative Overview of Provisional Personas (G1, G2, G3).

The following table presents a structured comparison of four provisional personas, corresponding to their respective user group as defined in WP1. It synthesises key behavioural traits, digital competencies, narrative preferences, and interaction expectations observed during the early research phase. This overview may serve as a practical design tool to support iterative development processes, prioritisation of functional features, and inclusive narrative strategies in the subsequent stages of the project (notably WP2 and WP3).

Table 2. Comparative overview of provisional user personas representing G1-G3.

Persona	**Group**	**Digital competence**	**Motivations**	**Narrative preferences**	**Functional requirements**	**Sensitivities / Challenges**
Curious Synthesiser	G1	Moderate	Engagement, understanding, personal relevance	Emotional, contextual, partially guided storytelling	Clear navigation, logical structure, contextual framing	Prone to disorientation; difficulty interpreting immersive spaces
Structured	G1	Medium (low in	Pedagogical value, clarity,	Coherent, structured,	Intuitive interface,	Concern about cognitive

Facilitator		immersive tech)	adaptability for learning	didactic narrative	educational alignment, interpretative control	overload; aversion to ambiguity
Reflective Performer	G2	Varied (aesthetic literacy high)	Inspiration, emotional depth, interpretative openness	Non-linear, symbolic, performative, emotionally layered	Freedom to explore, aesthetic richness, minimal constraints	Dislikes overly prescriptive formats; prefers expressive openness
Strategic Integrator	G3	Very high	Functionality, reusability, technical integration	Modular, goal-driven, customisable content	Technical reliability, flexible control, exportability	Low tolerance for inconsistency; demands production-readiness

This Table 1 summarises the defining characteristics of four provisional personas developed during Task 1.1.3. Each persona reflects typical behavioural patterns, digital competences, motivational profiles, narrative preferences, and functional expectations observed among users belonging to the three primary groups defined in WP1: G1 (students and educators), G2 (artists and art school teachers), and G3 (professionals from the Cultural and Creative Industries). The matrix offers a condensed visual reference to support user-centred design decisions and alignment with diverse experiential contexts.

This comparative matrix builds upon the user segmentation and characterisation framework developed in *Deliverable D1.1 -Methodological Framework and User Groups Definition* (Krakowska et al., 2024). The construction of provisional personas is explicitly foreseen in Task 1.1.5, where personas are defined as synthesised user archetypes reflecting observed needs, practices, and expectations across user groups (Krakowska et al., 2024, pp. 22-23). According to the methodology outlined in WP1, provisional personas are derived from:

- the initial desk-based profiling and segmentation of user groups (G1-G3) presented in D1.1;
- thematic insights obtained from interviews, surveys, and participatory observation conducted in Task 1.1.3;
- established UX research practices based on the ISO 9241-210 framework for human-centred design, in which personas are recognised as design tools bridging empirical user data and system development decisions.

The personas presented here serve as intermediate conceptual models, guiding the ongoing development of narrative strategies, user journeys, and interface structures.

They will be subject to further validation and refinement in subsequent empirical activities within Task 1.1.5, and in co-design sessions planned under WP2.

6.4 Use-case Taxonomy and Intended Outcomes

To ensure clarity and traceability between user research, design recommendations, and evaluation, this taxonomy organises the use cases by user group. Each case outlines the primary focus and the *intended outcomes* emerging from the research. These outcomes illustrate *how* different communities may benefit from the IMPULSE platform and *what types of practices it aims to support*, without implying that all functionalities will be implemented within the current project scope.

G1 -Education (students, teachers, researchers)

Use-case focus:

Integration of immersive cultural heritage (CH) into curricula, support for didactic innovation, and enhancement of digital literacy in higher education.

Intended outcomes:

Increased student engagement and memorability of CH content.
Development of critical digital and information competences.
Support for inquiry-based and experiential learning methods.
Strengthened teacher-student interaction in immersive environments, including guided tours and co-creative exchanges.
(The full "blurring of roles" between learners and educators remains an aspirational direction for future research rather than a deliverable within IMPULSE.)

G2 -Artistic Research and Creative Practice (artists, art educators, practitioners)

Use-case focus:

Exploration of immersive CH assets as material for creative reinterpretation, speculative design, and new aesthetic forms.

Intended outcomes:

Expansion of creative methodologies through XR/MUVE.
Development of new artworks, performances, or teaching formats inspired by CH content.
Strengthened capacity for interdisciplinary co-creation.

Increased visibility and valorisation of cultural heritage within the creative industries.

G3 -Cultural and Creative Industries (CCI professionals, curators, designers, developers)

Use-case focus:

Professional adoption of immersive CH tools in exhibition design, digital curation, and cultural mediation.

Intended outcomes:

Improved workflows for CH digitisation, curation, and exhibition design.
New hybrid service models (e.g., remote co-creation, blended exhibitions).
Validation of interoperability and scalability standards.
Stronger collaboration between CH institutions and creative industries.

Cross-cutting outcomes (all groups)

Inclusivity: Broader access to CH through inclusive participation models.
Sustainability: Support for long-term re-use of digital CH assets.
Community building: Expansion of the Community of Practice across all user groups.

Table 3. Use-case Taxonomy and Intended Outcomes

User Group	Use Case	Intended Outcomes (WHY)
G1 -Education (students, teachers, researchers)	Integration of immersive CH into curricula; support for inquiry-based learning	• enhanced engagement and memorability of CH content • development of digital & information competences • strengthened teacher-student collaboration
G2 -Artistic Research & Creative Practice (artists, art educators, practitioners)	Creative reinterpretation of CH through XR/MUVE; development of new artistic methodologies	• expansion of creative practices via immersive tools • new artworks, performances, or teaching formats • strengthened social co-presence and interdisciplinary collaboration • greater valorisation of CH in creative industries
G3 -Cultural & Creative Industries (CCI professionals, curators, designers, developers)	Professional adoption of immersive CH tools for curation, exhibition & workflows	• improved digitisation & exhibition workflows • new hybrid service models (remote curation, co-creation) • validation of interoperability & scalability • stronger CH-CCI collaboration

Cross-cutting outcomes (all groups)	Inclusivity, accessibility, sustainability, and community of practice	• broader access to CH assets • long-term re-use of digital heritage • growth of a transdisciplinary Community of Practice

7 Methodology

The empirical UX research presented in this deliverable was grounded in a user-centred and iterative design approach, as defined in *Deliverable D1.1* (Krakowska et al., 2024) and aligned with the ISO 9241-210 standard for human-centred interactive systems. The overarching goal was to generate actionable insights into how diverse user groups engage with immersive digital heritage experiences.

A triangulation of methods was employed to ensure both depth and breadth of insight:

- Participatory workshops enabled live observation and co-creation in controlled immersive settings;
- Structured surveys captured attitudinal and experiential data across larger respondent samples;
- Semi-structured interviews elicited detailed individual perspectives, interpretative frames, and usage contexts.

This multi-method strategy was designed to accommodate the complexity of immersive experience design, balancing exploratory openness with comparative consistency across user groups and cultural content types.

7.1 Methodological Framework

The UX research conducted within Task 1.1.3 of the IMPULSE project was grounded in a user-centred, iterative and exploratory methodology, designed to capture diverse user perspectives on immersive digital cultural heritage experiences. This approach builds directly on the framework laid out in *Deliverable D1.1 -Methodological Framework and User Groups Definition* (Krakowska et al., 2024), and is aligned with the principles of the ISO 9241-210 standard for human-centred design of interactive systems (ISO, 2019).

7.1.1 User-centred and Iterative Approach.

In accordance with the overall vision of WP1, the study placed real users: students, educators, researchers, artists and CCI professionals at the centre of the design and evaluation process. Rather than testing predefined assumptions or fixed functionalities, the aim was to engage users in dynamic, creative and reflexive

interactions with the prototype and with each other. The research was iterative, allowing feedback to inform not only interpretation but also the redesign of survey instruments and the evolution of prototype components.

The study recognised that immersive user experience is shaped not only by usability, but also by emotional resonance, cognitive framing, social background, and contextual expectations. Therefore, the methodology sought to account for these multidimensional aspects of user engagement through a careful combination of qualitative and quantitative tools.

User participation occurred at several levels:

- as co-creators of spatial narratives during the Leuven workshop;
- as evaluators of interface and content coherence via structured questionnaires;
- as informants and interpreters through individual and expert interviews.

This layered engagement was crucial for understanding not just what users do within immersive environments, but how they make sense of them, what values they assign, and what barriers they encounter.

7.1.2 Triangulation of Methods.

To ensure the robustness, depth and credibility of the findings, the research adopted a triangulation strategy combining three complementary methods:

1. **Participatory UX Workshop (Leuven).**
   Designed as a co-creative and exploratory environment, the workshop enabled real-time observation of user interaction with the prototype, spontaneous feedback, and collaborative scenario development. It produced data in the form of group observations, design sketches, materials shared via Miro and Discord, field notes, and post-task survey responses.
2. **Quantitative Surveys (G1 & G2).**
   Online surveys provided a structured means to collect data from broader samples of target users, enabling statistical comparison of perceived usability, immersion, clarity, and narrative relevance. The survey design was informed by pilot observations and refined between iterations.
3. **Semi-structured Interviews (G1-G3 + Experts).**
   Interviews captured individual reflections, interpretative logics, affective responses, and broader professional or educational expectations. They provided insight into long-term familiarity with XR systems, narrative interpretation, and context-specific needs.

This triangulated framework allowed for:

- cross-verification of insights across data types;

- contextual anchoring of quantitative results in user narratives;
- synthesis of shared themes and identification of group-specific variations.

The integrated methodological design also reflects the ambition of WP1 to combine theoretical innovation (in narrative and interaction design) with empirical grounding in the lived experiences of cultural heritage users.

7.2 Tools and Instruments

The empirical study conducted within Task 1.1.3 required the development and application of research tools capable of capturing nuanced, multidimensional aspects of user experience across different contexts of interaction. Instruments were designed to reflect both the diversity of user profiles (G1-G3) and the multimodal nature of immersive cultural heritage engagement. Each tool addressed a different dimension of the UX landscape: experiential immersion, usability, affective response, cognitive interpretation, and narrative preference. Their complementary application allowed for cross-validation of findings and the integration of both quantitative and qualitative user perspectives.

The key instruments included: (1) scenario-based UX testing protocols, (2) structured questionnaires for on-site and remote data collection, and (3) tailored semi-structured interview guides.

7.2.1 UX test scenarios.

To structure user interaction with the early-stage IMPULSE prototype and to probe how users interpret, navigate, and emotionally engage with cultural heritage content in immersive environments, a set of UX test scenarios was developed and implemented by the KU Leuven team specifically for the two-day participatory workshop in Leuven (February 2025). These scenarios, which reflect the preparatory work and creative ideation carried out by KU Leuven in advance, guided participants through narrative ideation, spatial storytelling design, and live testing in the VR platform, enabling structured observations and post-task evaluations.

7.2.1.1 Scenario Architecture and Purpose.

The test scenarios were not abstract tasks but were rooted in curated historical themes and artefact sets, assigned to each team. Each group worked with different content types (e.g. Palmyra, Vesalius, mythological reliefs) to develop immersive story experiences. The scenario process unfolded in three interdependent phases:

1. Ideation and Narrative Development (Day 1):
    a. Participants explored a curated collection of digital heritage artefacts and assigned themes.
    b. Through guided exercises using story prompt cards, they brainstormed possible narrative angles, emotional framings, and learning outcomes.
    c. Teams discussed key storytelling questions: What message should the visitor take away? What affective response do we want to trigger?
2. Spatial Storyboarding and Scenario Structuring (Day 1-2):
    a. Using sketching tools, Miro boards, and the principles of Juxtaposition, Sequence, and Perspective, teams developed spatial layouts and interaction flows.
    b. They mapped story arcs through object arrangement, spatial pacing, and user movement expectations, simulating museum-like or exploratory narrative journeys.
3. Immersive Scenario Testing (Day 2):
    a. Participants reconstructed their story layouts in the actual VR environment and walked through the scenarios as both creators and test users.
    b. Teams tested: Does the artefact placement support the story? Are transitions between themes legible? Is the visitor's attention guided meaningfully?
    c. After internal walkthroughs, cross-team feedback sessions allowed fresh perspectives and evaluative insights.

Each test scenario thus functioned as a full-stack experiential unit, from ideation to prototype instantiation, simulating future visitor experiences and surfacing design constraints.

7.2.1.2 Roles in Scenario Facilitation.

The scenarios were facilitated through a dual role structure, as defined in the facilitation script:

- The Team Lead ensured the progression of tasks, team dynamics, and structural consistency. They supported group synthesis and maintained documentation of design decisions.
- The Storytelling Expert introduced theoretical concepts (e.g. spatial narrative techniques) and mentored teams in aligning emotional, educational, and curatorial goals. Their role was particularly crucial in enabling participants to shift from linear storytelling to immersive, interactive modes of representation.

This combination enabled participants to co-create immersive narratives while remaining critically aware of interaction logic and affective design.

7.2.1.3 Scenario Objectives and Observational Strategy.

The UX test scenarios were designed to fulfil several concurrent aims:

- Stimulate co-creative exploration of immersive narrative forms;
- Surface experiential challenges related to navigation, content interpretation, and sequencing;
- Evaluate users' intuitive engagement with cultural material in VR;
- Generate actionable feedback on interface design, cognitive load, and affective resonance;
- Support the creation of personas and user journeys, as further elaborated in Section 6.

Structured observation protocols were used during scenario execution, alongside post-task surveys and live annotations by researchers. These materials formed a critical dataset for the triangulation of insights across groups and methods.

7.2.2 Survey Questionnaires.

Two distinct survey instruments were employed during Task 1.1.3, both developed collaboratively by JU and KU Leuven to address the needs of the UX study. While both shared a common structure, they were applied in different contexts and served complementary research purposes.

1. **Workshop Evaluation Questionnaire (JU).** The first questionnaire was designed specifically for the participatory UX workshop conducted in Leuven in February 2025. This two-day event, hosted at the Agora Learning Centre of KU Leuven, served as a co-creative exploration of how immersive technologies particularly VR can transform engagement with cultural heritage and educational content. Participants engaged with early-stage IMPULSE prototypes developed using authentic digital cultural assets (e.g. Vesalius manuscript, Palmyra reconstructions, hybrid mural simulations), and were invited to test, reflect and co-design immersive storytelling strategies. Questionnaire for Leuven workshop is available in **Appendix 11.1** and all materials for partners and participants of Leuven workshop is available on MS Team WP IMPULSE General Group, available at: https://teams.microsoft.com/l/team/19%3A9mNtT4kob1TQolvDLWRi6KWOsSHQPRVIK1QQKwjLHxo1%40thread.tacv2/conversations?groupId=39f4586f-e918-473a-8b46-e27f90217b45&tenantId=eb0e26eb-bfbe-47d2-9e90-ebd2426dbceb).

The workshop was conceived as an open, interdisciplinary environment welcoming educators, artists, cultural mediators and curious participants from diverse backgrounds. No prior technical experience was required. The emphasis was placed on collaboration, imagination and critical reflection. Participants experimented with prototype scenarios, interacted with content, and engaged in structured and informal feedback sessions.

To evaluate user reactions and gather structured insights, JU administered an on-site post-interaction questionnaire that captured:

a. initial emotional and sensory reactions to immersive interaction;
b. perceived clarity and usability of the interface;
c. preferences regarding content structure, aesthetic qualities, and accessibility;
d. self-assessed digital literacy and creative background.

JU was responsible for creating the anonymous UX questionnaire in collaboration with WP2. Once it was confirmed that no personal data would be processed, the KU Leuven ethics committee advised that ethical review was not necessary. KU Leuven's obtained participants' consent for GDPR purposes specifically related to the use of images and videos taken during the workshop.

2. **Formalised Survey for Remote Study (Jagiellonian University)**. Building on the design and insights of the Leuven questionnaire, a revised and extended survey was developed by the Jagiellonian University for remote deployment. This instrument reflected improvements outlined in *Deliverable D1.1*, including enhanced granularity of usability metrics and additional open-ended prompts for interpretative feedback (Krakowska et al., 2024, pp. 25-27).

This version targeted broader segments of G1 (students and educators) and G2 (artists and art teachers). It was distributed online using a GDPR-compliant platform and collected both quantitative data (via Likert-scale items) and qualitative reflections. Items assessed immersion, accessibility, narrative coherence, perceived educational or expressive value, and user confidence with XR tools.

The structured comparison between workshop-based and remote data allowed for cross-validation of thematic findings and provided a basis for developing differentiated design recommendations across user groups.

7.3 Ethical and Logistical Considerations.

All research activities conducted as part of Task 1.1.3 complied with the ethical standards of the IMPULSE project, as defined in the Data Management Plan (D5.1) and in line with the European Code of Conduct for Research Integrity (ALLEA, 2023). Specific ethical procedures varied depending on the nature of the data collection method and the institution responsible for implementation.

For the participatory UX workshop in Leuven, KU Leuven being the hosting and organising partner -was responsible for ensuring ethical oversight and procedural compliance related to its specific role. This included:

- informing participants about the use of images and videos taken during the workshop;
- obtaining signed consent forms specifically for GDPR purposes concerning those materials;
- safeguarding participants' rights to withdraw at any point;

The anonymous UX questionnaire used during the session was created by JU in collaboration with WP2. Since the questionnaire did not involve the processing of personal data, KU Leuven's ethics committee determined that formal ethical approval was not required. The Microsoft Form used to collect the anonymous responses contained information about consent, ensuring that participants were informed about the voluntary nature of their participation and the anonymous handling of their data.

For the surveys and interviews conducted under the leadership JU, the following safeguards were implemented:

- Informed consent was collected digitally prior to survey access or interview scheduling;
- Survey responses were fully anonymised, and transcripts were pseudonymised during processing;
- Data were stored on secure, GDPR-compliant institutional servers;
- Only members of the authorised research team had access to raw data;
- The instruments were reviewed internally by JU's ethics liaison for compliance with both institutional and Horizon Europe standards.

All activities followed the principles of voluntary participation, non-intrusiveness, and data minimisation, and were conducted in accordance with the FAIR principles to ensure the findability, accessibility, interoperability and reusability of research data in subsequent tasks (notably D1.3 and WP2 user testing protocols).

7.4 Data Sources for the Evidence Plan

To ensure the reliability and interpretive depth of the findings, IMPULSE adopts a **multi-source evidence strategy** combining quantitative and qualitative methods. This approach strengthens the empirical basis of the user research, provides traceability from evidence to design recommendations, and supports subsequent evaluation in WP2-WP5.

The following complementary data sources were employed or are planned for subsequent testing phases:

(1) System-generated data (platform logs and interaction analytics)

Description: Automatic recording of user interactions within the IMPULSE prototypes and MUVE environments.

Examples of indicators: login frequency, session duration, object manipulations, navigation paths, and collaborative actions.

Relevance: Provides behavioural evidence of engagement, usability, and interaction patterns in immersive environments.

(2) Task performance and timing (structured experiments)

Description: Controlled or semi-structured tasks performed during workshops, pilots, and testing sessions.

Examples of indicators: task completion rate, average completion time, learning curve, recovery after errors.

Relevance: Offers quantitative insight into the usability and learnability of core platform features.

(3) Surveys and questionnaires

Description: Pre-and post-experience surveys distributed across user groups (G1-G3).

Examples of indicators: perceived engagement, learning value, creative stimulation, accessibility, and inclusivity.

Relevance: Captures subjective evaluations of immersive experience and perceived added value for education, creativity, and professional use.

(4) Observations and ethnographic notes

Description: In-situ observation of workshops, residencies, and testing sessions by researchers.

Examples of indicators: affective reactions, collaboration dynamics, spontaneous problem-solving, and embodied engagement.

Relevance: Provides contextual and behavioural data that complement quantitative results, supporting a holistic interpretation of user experience.

(5) Semi-structured interviews and focus groups

Description: Post-experience discussions recorded and analysed thematically.

Examples of indicators: perceived usefulness, barriers, motivations, and the value of co-creation and reuse of CH assets.

Relevance: Adds interpretive depth to the analysis of high-level goals such as storytelling, collaboration, and sustainability.

(6) Cross-context adoption and dissemination evidence

Description: Documentation of the uptake of IMPULSE prototypes, methods, and insights in courses, artistic projects, or CH institutions.

Examples of indicators: number of pilots or workshops, references in artistic or educational outputs, adoption by CH organisations.

Relevance: Demonstrates the broader applicability and sustainability potential of IMPULSE outcomes beyond the immediate project scope.

8 UX Research Activities and Results

This section presents the findings of the multi-method user research conducted within Task 1.1.3. The results are interpreted in relation to the experience goals defined in Section 5.6, ensuring that the empirical evidence (what users do, perceive, and expect) is directly linked to the project's strategic and experiential objectives (why the platform matters).

The analysis confirms that many of the high-level goals -such as engagement with cultural content, inclusivity, and collaborative co-presence -were not only identified in the literature but also strongly evidenced in the empirical data (see Sections 8.1-8.3). In parallel, several recurring functional expectations emerged across user groups and methods, including intuitive navigation, role-based collaboration, and simple but flexible storytelling mechanisms.

Together, these findings establish the evidence base for the design recommendations and functional framework outlined in Section 9. Rather than prescribing features, they indicate priorities and feasible directions for further prototyping and testing within the scope of WP2.

8.1 Participatory UX Workshop (Leuven)

As part of the participatory design strategy adopted in the IMPULSE project, a co-creative UX workshop was conducted at KU Leuven, involving participants from three defined user groups: G1, G2 and G3. Organised by the entire KU Leuven team, including Digit GLAM as part of WP1 and KU Leuven as the WP3 leader, the workshop constituted a structured and adaptive research intervention designed to explore the narrative, pedagogical, and experiential dimensions of immersive technologies in the context of cultural heritage.

Originally, the session was expected to facilitate direct, scenario-based interaction with the IMPULSE VR prototype. However, due to critical technical malfunctions (described in detail in Section 8.1.2), the workshop was restructured as a hybrid methodological activity, combining speculative co-design, storyboard-based prototyping, affective narrative ideation, and reflective user feedback. This adaptation transformed the session into a valuable dual-purpose exercise, yielding both grounded experiential insights and aspirational design inputs.

8.1.1 Objectives and Structure.

The workshop pursued several interlinked objectives:

- To investigate how digitised 2D historical materials can be creatively recontextualised in a 3D immersive environment;
- To identify opportunities for implementing cross-temporal storytelling and collaborative narration within immersive systems;
- To elicit reflective feedback on user expectations, perceived limitations, and desired affordances;
- To formulate detailed design-oriented recommendations in light of prototype constraints.

Participants were divided into four interdisciplinary teams, each working with selected digital assets from KU Leuven Libraries, including:

- Digitised folios from the Vesalius' annotated Fabrica,
- Glass slides depicting archaeological artefacts, mural fragments, and scientific visualisations,

Each team followed a structured design sequence, including:

- Collaborative scenario building on shared Miro boards;
- Flowchart development and storyboard creation to illustrate potential user pathways and narrative logic;
- Conceptual design discussions focused on user emotion, spatial immersion, and cultural relevance.

Despite the absence of direct system interaction, the participants demonstrated high levels of creative engagement and conceptual immersion. Key outcomes included the emergence of speculative metaphors and interaction motifs such as:

- "Vesalius meets the Egyptian embalmer": suggesting historical cross-temporal dialogue scenarios;
- "From floor plans to embodied rituals": reflecting embodied memory and spatial practice;
- "Personal curation of fragments": foregrounding agency, personalisation, and user-defined meaning-making.

8.1.2 Preliminary Design Recommendations.

Synthesised from group outputs, participant discussions, and facilitator observations, the following initial design recommendations were communicated to the WP2 development team:

- Integrate narrative affordances allowing for object annotation, combination, and storytelling;
- Develop customisable avatars and expressive environmental elements;
- Enhance onboarding processes, feedback cues, and interface legibility;
- Support real-time collaboration and shared presence in immersive space;
- Provide fallback testing modes to safeguard against prototype instability.

8.1.3 Description of the Prototype and Testing Scenarios.

The version of the IMPULSE immersive platform deployed during the Leuven workshop represented an exploratory pre-alpha prototype, developed by WP2. The platform was intended to serve as a web-accessible immersive environment for creative interaction with digital cultural heritage resources, with a particular emphasis on spatial storytelling, object manipulation, and avatar-based navigation.

Built using Unity for the client and PHP for the backend, the prototype offered partial support for modular scene construction, content import, and user navigation via an HTTP API. The full range of functionalities, including customisation tools, has not yet been implemented as foreseen in the platform work plan.

8.1.4 Intended Testing Scenarios and Constraints.

The prototype was intended to support exploratory use cases involving:

- Importing, positioning, and narratively combining digitised cultural materials;
- Navigating through constructed scenes via avatars;
- Experimenting with storytelling configurations and interpretive structures.

Due to network and connectivity issues with the server, most participants were unable to access the platform as intended. While the basic functionality of the prototype was developed and operational, many participants did not have the opportunity to test it. Consequently, the workshop was restructured to focus on:

- Static observation of available prototype functions;
- Externalised narrative design using collaborative tools (see 8.1.1);
- Survey-based reflection on expectations and encountered barriers.

Although not fully operational, the prototype served as an early-stage conceptual framework that participants critically engaged with and reimagined. This stage is **crucial** for identifying and addressing technical issues while exploring design possibilities. The Leuven workshop thus functioned both as an empirical usability probe and a speculative design intervention. The insights generated during this hybrid session directly informed the qualitative UX analysis (see Section 8.1.6) and contributed to refining the functional roadmap for the next iteration, developed by WP2.

8.1.5 Observations, Interactions, and Participant Statements.

Despite the technical issues experienced with the prototype during the Leuven workshop, the data collected from participant interactions, including outputs from Miro boards and discussions on Discord, provided valuable insights into user expectations, challenges, and creative thinking. The workshop was structured in a way that encouraged speculative design and scenario development, which allowed participants to engage creatively with the platform despite its technical limitations

Forms of Interaction Observed.

Forms of interaction were recorded through a combination of facilitator logs, participant feedback, and group reflections. Key interactions observed included:

- VR-based gestures: Due to the lack of headsets or cameras for gesture recognition during the Leuven workshop, users were unable to test gesture-based controls. However, participants did engage with the platform's avatar interactions, such as basic hand movements (e.g., waving) via the available input devices. Technical issues, including movement registration failures and platform instability, limited the effectiveness of these avatar gestures, highlighting the need for more precise feedback on interaction status and improvements in gesture-based avatar control systems.
- Desktop-based interactions: Participants using desktop systems, primarily with keyboard and mouse, made efforts to scale, rotate, and position 2D objects onto 3D primitives. These interactions were often difficult to perform accurately, with many users expressing frustration over precision errors in object placement and manipulation.
- Collaborative storytelling: Participants engaged in collaborative discussions and visual storytelling, often referencing the cultural artefacts provided, such as Pages from Vesalius' annotated Fabrica and Glass slides depicting archaeological sites. Even with limited interaction, users-built narratives based on the objects available.
- Metaphorical expressions: When facing technical challenges or limitations in interaction, participants expressed their conceptual intentions through metaphors like *"time-travel gallery"* and *"curator's dream space"*, which pointed to a desire for creative flexibility and interactive depth that was missing from the current system.
- Workarounds: Users employed various manual workarounds, including sketching narratives on paper or verbally simulating the desired user interactions (such as avatar actions or movement). These adaptive behaviours emphasized the need for more natural interaction paths.

Table 4. UX Themes Observed in Practice.

UX Dimension	Observed Behaviours and Comments
Navigation	Trial-and-error movement; confusion over directional control
Object Interaction	Frequent misplacement, unstable object behaviour, lack of feedback
Avatar Presence	Emotional distance; avatars seen as symbolic rather than embodied
Expressivity	Users mimicked expressions through gestures; desire for affective tools
Co-presence	Absence of voice/chat noted; participants "performed" interactions manually

8.1.6 User Group-Specific Results: G1, G2, G3.

This section provides a comparative analysis of user responses across the three user groups, as defined in D1.1 (G1: students, academic teachers and researchers, G2: artists and art school educators, and G3: cultural and creative industries professionals).

Methodological Approach.

Although the survey data did not explicitly label participants by group, we used a triangulation approach to assign users to these groups based on:

1. Workshop group assignment and participant role (facilitator records),
2. Content of qualitative responses (coded in Annex B),
3. Observed behavioural patterns and narrative engagement during the session.

G1 -Educators, Researchers and Students.

Perceptual Orientation.

G1 participants approached the prototype with a strong need for clarity, onboarding guidance, and reliable pedagogical tools. They expected intuitive controls and an educationally coherent framework.

Key Difficulties:

- Difficulty understanding how to import and manipulate content,
- Lack of scaffolding tools or step-by-step tutorials,
- Frustration with platform instability, especially for users unfamiliar with VR.

Notable Engagement:

G1 participants proposed concrete educational use cases, such as:

- *Anatomy-based learning* using Vesalius drawings,
- *Object-based learning* with artefacts,

- *Speculative interdisciplinary modules* where historical materials were placed in a futuristic narrative.

G2 -Artists, Art Teachers and Creative Practitioners.

Perceptual Orientation.

G2 users saw the platform as an opportunity for creative expression, narrative construction, and emotional immersion. They were most excited by the aesthetic potential of the platform, even though the system was unstable.

Key Difficulties:

- Lack of avatar customisation and expressive presence,
- No tactile feedback when interacting with objects,
- Difficulty simulating time-based narratives, especially in performance scenarios.

Notable Engagement:

Despite the technical limitations, G2 participants imagined:

- *"Ritual reactivation environments"* to engage in immersive cultural practices,
- *"Embodied memory walls"* to allow interaction with 3D representations of fragmented memories,
- *Dramaturgies of fragmented heritage* that allow users to perform narratives.

G3 -Cultural Sector Professionals and Creative & Cultural Industries.

Perceptual Orientation.

G3 participants focused on interpretive fidelity and responsible representation of cultural heritage. They emphasised the importance of contextualised, multi-layered narratives that engage both the user and the artefacts.

Key Difficulties:

- Inability to anchor metadata to objects in the scene,
- Lack of multi-user functionality for collaborative curatorial tasks,
- Concerns about the authenticity and provenance of virtual artefacts.

Notable Engagement:

G3 participants conceptualised use cases, including:

- Personalised digital exhibitions, allowing users to curate collections,
- Fragment-based storytelling, where users add their own interpretation to incomplete historical narratives,

- Visitor-generated narratives, integrating user contributions as part of the interpretive process.

Table 5. Cross-Group Comparative Summary.

Dimension	G1	G2	G3
Primary Expectation	Clarity, educational logic	Expressivity, embodiment	Curation, context, reliability
Reaction to Prototype	Cautious; usability concerns	Imaginative; high tolerance	Analytical; emphasis on structure
Main Barrier	Lack of guidance, instability	Limited expression, missing tools	Incomplete context, insufficient control
Commitment Level	Moderate, conditional	High	High (conditional on functionality)

8.1.7 Storytelling Scenarios and Narrative Prototyping (Leuven Workshop).

As an integral part of the Leuven participatory design process, four interdisciplinary teams engaged in speculative storytelling exercises using selected heritage assets from KU Leuven Libraries' collections. The goal was to explore how diverse user groups (educators, creatives, curators, researchers) conceptualise immersive cultural narratives under conditions of limited technical operability but high conceptual potential.

The storytelling exercises were intentionally conducted in a low-fidelity, speculative mode due to the technical constraints of the prototype (see Section 8.1.2). However, participants engaged deeply with the narrative affordances of 2D and 3D cultural objects, emphasising the potential of immersive experiences for creative exploration and cross-temporal encounters. These observations align directly with high-level goals such as WHY 2 (memorability and learning benefits) for G1, WHY 4 (creative reinterpretation) for G2, and WHY 7 (interoperability and re-use) for G3. At the same time, G1 participants also valued opportunities for collaborative exploration, which links to WHY 5 (social co-presence and co-creation). For Group 1, IMPULSE additionally explores the blurring of teacher-student hierarchies, fostering bottom-up co-creation and counter-narratives in educational contexts.

Method and Structure.

Each team worked with a dedicated set of curated digital materials. Their tasks included:

- Selecting a central narrative or interpretive path,
- Designing a user journey, interaction flow, or activity scenario,

- Mapping user roles and emotional/aesthetic dynamics,
- Identifying missing functionalities or barriers,
- Reflecting on ethical considerations related to the use of heritage objects.

The data were collected through the use of concept sketches, written vignettes, collaborative flowcharts, and critical reflection documents. The prototype utilised during the workshop in Leuven exhibited the following characteristics and constraints:

Team 1: Ancient Places, Living Heritage.

Planned Materials: digitised glass slides of archaeological sites, including Palmyra, Baalbek, Jerash, and Dendera; floor plans, architectural fragments, excavation images; 3D reconstructions (KU Leuven Workshop -Storytelling, available at: https://ujchmura.sharepoint.com/:w:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials/KU%20Leuven%20Workshop%20-%20Storytelling_preparationForLeuven.docx?d=w146c9cd7f4274efdbf3e7a75b0738d26&csf=1&web=1&e=npzGDg).

Original Narrative Concept (based on KU Leuven Workshop -*Storytelling*): This team was invited to reimagine iconic archaeological sites as living, evolving environments. The core prompt encouraged participants to explore how these ancient places -from the grandeur of Palmyra to the intricacies of Dendera -could be transformed into immersive, educational experiences. Using glass slides depicting temple layouts and excavation scenes, the team was guided to construct stories about the rituals, social life, and technological achievements that once animated these spaces. A speculative angle -"What if Palmyra had never fallen?" -invited participants to envision alternate historical trajectories and cultural continuities, using immersive storytelling to bridge the past and the present.

Workshop Execution and Adaptation:

During the session, participants engaged in scenario-building based on these archival materials but also adapted the original brief to foreground the multiplicity of perspectives embedded in archaeological interpretation. Instead of constructing a linear reconstruction of ancient life, the team gravitated towards exploring the fragmented nature of historical knowledge. This led to the creation of a multi-perspective framework, where users could "step into the shoes" of various roles -an archaeologist, a local inhabitant, a 19th-century photographer -each offering partial, situated insights into the same space.

Key Features:

- A role-swapping mechanism, enabling users to explore the same heritage space from distinct socio-historical viewpoints.
- Layered data visualisation: overlapping historical narratives based on different artefactual interpretations.
- A temporal navigation tool, allowing users to trace changes across time - including speculative futures.

Identified Gaps:

- Absence of guided, dynamic perspective-switching functionality (currently requiring manual reinterpretation).
- Need for tools to support layered annotations and multimodal storytelling, especially when navigating conflicting heritage narratives.
- Limited interaction with certain archival materials (e.g., some slides or 3D models remained unused due to time or technical constraints).

User Roles (narrative-based):

In the file entitled "KU Leuven Workshop -Storytelling", the section dedicated to Band 1 contains concrete examples of the narrative application of social or professional roles to represent different perspectives on cultural heritage. The text under consideration comprises the following: *"How can glass slides of temple floor plans, architectural details, or excavation images inspire stories about the rituals, innovations, and people that shaped these places?", "An excavation image leads to a story about the rediscovery of forgotten artifacts, or the archaeologists' struggles to preserve them.", "A floor plan of an ancient temple inspires a story about a festival held there.", "What if Palmyra never fell?... How would they have evolved into the present day?" It is evident that these recommendations call upon participants to adopt perspectives, such as those of an archaeologist, a local resident, or a historian. Furthermore, the role of the photographer was proposed as a means of narrating the glass slides, which constituted a primary source material. Although not formally designated as "user roles," these individuals served as narrative test roles, i.e., roles that users were expected to "act out" as part of immersive scenario design.*

Roles were assigned as part of the scenario-facilitation strategy and not reflective of participants' real-world identities. These included:

- The Archaeologist: interpreting excavation layers and artefacts.
- The Photographer: capturing and framing heritage through early visual media.
- The Local Resident: offering vernacular, embodied memory of place.
- The Historian: contextualising fragments within broader cultural narratives.

These roles were created to enable multivocal engagement with the content, prompting participants to question how heritage is curated, visualised, and made meaningful across time. The following excerpt is taken from a plan, as well as actual material developed during a two-day workshop in Leuven. The workshop materials are available at the following address: https://ujchmura.sharepoint.com/:f:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials?csf=1&web=1&e=yB1SG4

Team 2: Anatomy of Discovery.

Planned Materials:

Vesalius manuscript (Vesalius' annotated *De humani corporis fabrica*) pages; digitised slides of anatomical drawings and mummified bodies; historical anatomical illustrations; references to early medical practices and dissection techniques (*KU Leuven Workshop - Storytelling*).

Original Narrative Concept (based on *KU Leuven Workshop -Storytelling*): Team 2 was invited to explore the evolution of anatomical knowledge and medical visualisation through immersive storytelling. The core narrative prompt centred on the intersection between historical medical representations -from Vesalius' anatomical drawings to glass slides of preserved specimens -and contemporary understandings of the human body. Participants were encouraged to reflect on how these static, two-dimensional materials could be reimagined in a tactile, spatial, and affectively engaging manner within a virtual environment. A critical speculative scenario -*"What if Vesalius had been a woman?"* -prompted reflection on gender, authority, and representation in the history of medical knowledge.

Workshop Execution and Adaptation:

During the Leuven workshop, participants interacted with digitised historical materials including Vesalius's illustrations and interpretive texts describing early dissection practices. The original narrative was expanded beyond anatomical linearity to include culturally and temporally layered understandings of the body. Participants created spatial scenarios juxtaposing precision-driven scientific visualisation with affective and embodied interpretations. Rather than presenting dissection as a solely clinical act, the team staged epistemic encounters between historical anatomists and contemporary users, interrogating the pedagogical and ethical dimensions of visualising the human body. A modular narrative structure emerged, reflecting episodic transitions between past, present, and speculative futures -including Egyptian embalming rituals and futuristic anatomy labs, as described in the storyboard (*Storyboarding_Leuven_Workshop.docx* available at

https://ujchmura.sharepoint.com/:w:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials/Storyboarding_Leuven_Workshop.docx?d=wf1a50d6c2297479e8955813bcce8f32e&csf=1&web=1&e=TWzOh5).

Key Features:

- Layer-based interaction system to simulate the uncovering of anatomical structures in a controlled pedagogical sequence.
- Hotspot-driven annotations linking specific body parts with historical uses or cultural-symbolic meanings.
- Timeline interface contextualising Vesalius' work in a longue durée trajectory of anatomical inquiry.

Identified Gaps:

- Limited collaborative functionalities, constraining simultaneous user annotation or discussion during anatomical exploration.
- Incomplete 3D anatomical modelling, including surface detail and depth limitations which reduced embodied realism.
- Lack of gender perspective integration, particularly tools supporting speculative re-narration of scientific authorship and representation.

User Roles (narrative-based):

Drawing on the participatory strategy outlined in the *KU Leuven Workshop -Storytelling* document and implemented analogously to Team 1, the roles in Team 2 were designed as narrative testing roles. They enabled participants to assume epistemic and interpretive positions vis-à-vis the anatomical materials. These roles were not reflective of the participants' actual professions but were assigned to stimulate diverse perspectives within the immersive scenario.

Cited inspirations include narrative questions such as: *"What stories do these slides tell about early scientific inquiry?"* and *"How can educators use these virtual spaces to create interactive and engaging lessons?"* (*Team2_AnatomyOfDiscovery file* available at: https://ujchmura.sharepoint.com/:b:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials/Team2_AnatomyOfDiscovery.pdf?csf=1&web=1&e=QfFfMY). *T*he following excerpt is taken from a plan, as well as actual material developed during a two-day workshop in Leuven. The workshop material is available at the following address https://ujchmura.sharepoint.com/:f:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials?csf=1&web=1&e=yB1SG4).

Assigned roles included:

- The Anatomist: Interprets the dissection and visualisation of the human body; engages with Vesalius's materials to trace early scientific practices.
- The Medical Student: Learns through exploratory interaction with anatomical environments; serves as a proxy for contemporary educational uses.
- The Historian of Medicine: Contextualises materials within broader trajectories of medical epistemology, highlighting shifts in knowledge paradigms.
- The Speculative Scientist: Questions canonical narratives and explores alternative scenarios (e.g., gendered authorship in early anatomy).

These roles provided a multivocal narrative framework, enabling layered engagement with the material. The team used them to articulate differentiated user experiences and to test the pedagogical capacity of the VR space for diverse epistemic identities. The following excerpt is taken from a plan, as well as actual material developed during a two-day workshop in Leuven. The workshop material is available at the following address mentioned above.

Team 3: Reimagining Ancient Storytelling.

Planned Materials:

A curated selection of digitised glass slides depicting murals, reliefs, and mythological scenes from various ancient cultures, including Roman, Egyptian, and other Mediterranean civilisations. Artefacts include visual narratives such as Biblical stories in Roman murals and funerary imagery in Egyptian tombs. The objects are designed to reveal how ancient peoples encoded myths, religious ideas, and historical events into universal visual languages (*KU Leuven Workshop -Storytelling*; *IMPULSE Team 3.docx* available at https://ujchmura.sharepoint.com/:f:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials?csf=1&web=1&e=RXdmGX).

Original Narrative Concept (based on *KU Leuven Workshop -Storytelling*): This scenario invited participants to explore the role of visual storytelling across ancient civilisations and to reimagine how narratives were crafted, interpreted, and transmitted across different audiences and cultures. Central questions included: *How did murals and reliefs function as universal narratives? What if artists from different cultures collaborated on a shared visual story?* Participants were encouraged to craft immersive, layered stories inspired by fragments of ancient art, using speculative reconstructions and cross-cultural dialogues. The idea was not to reproduce history literally but to creatively re-envision how ancient storytelling might have transcended linguistic and cultural barriers. A speculative

scenario proposed imagining a collaborative mural between a Roman and an Egyptian artist, merging symbolic systems to create a hybrid narrative world.

Workshop Execution and Adaptation:

Team 3 approached the materials not as static records but as dynamic storytelling opportunities. Participants explored how juxtaposition, sequence, and perspective could reshape the viewer's journey through ancient narratives (*Exploring Key Spatial Storytelling Techniques.docx* available at https://ujchmura.sharepoint.com/:w:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials/Exploring%20key%20spatial%20storytelling%20techniques.docx?d=w8e3a64f05a5e4da28df4b0ba66f2688f&csf=1&web=1&e=gsxovT). Techniques such as layering, scaling, and shadow projection were employed to build fragmented, non-linear experiences where the audience could assemble meaning through movement, interaction, and emotional resonance.

Special emphasis was placed on the use of light, transparency, and shifting perspectives: users could zoom into fragments, reveal hidden layers, or navigate between overlapping temporalities and cultural viewpoints. Narrative openness -where stories unfold differently depending on the path taken -became a central feature of the immersive design.

Key Features:

- Juxtaposition and sequencing to generate emergent storytelling from mural fragments and artefacts.
- Dynamic light and shadow manipulation, enabling users to experience different emotional tones and narrative layers.
- Perspective-switching mechanisms, allowing navigation between cultural viewpoints and story threads.
- Speculative co-creation tools, inviting participants to imagine intercultural collaborations through interactive visual compositions.

Identified Gaps:

- Absence of collaborative real-time editing, preventing multiple users from layering or editing narratives together simultaneously.
- Limited emotional scaffolding, restricting the system's ability to represent affective dimensions such as reverence, mystery, or wonder.
- Lack of frameless exploration tools, inhibiting free-form narrative construction across visual artefacts.

User Roles (narrative-based):

Following the narrative facilitation model used in all teams, user roles in Team 3 were conceptualised as speculative personas designed to explore the dynamics of ancient storytelling through visual and spatial means, not as reflections of participants' real professions. These roles enabled participants to interpret, reframe, and transform ancient narratives creatively.

Roles included:

- Story Weaver: Constructs speculative, layered stories from fragmented visual materials, weaving cross-cultural myths and themes.
- Shadow Caster: Uses light, scale, and perspective to animate murals and reliefs, shifting emotional tones and focal points.
- Memory Keeper: Archives emergent interpretations and fragments, reflecting on the evolution and transmission of stories across time.
- Light Architect: Designs the spatial environment of light and shadow, enabling dynamic storytelling encounters.

These narrative-based roles supported the exploration of multiple interpretive layers, embodying the guiding idea: *"How might ancient artists have created stories that spoke across cultures, and how can we today reimagine these encounters in an immersive world?"* (*KU Leuven Workshop -Storytelling* available at: https://ujchmura.sharepoint.com/:w:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials/KU%20Leuven%20Workshop%20-%20Storytelling_preparationForLeuven.docx?d=w146c9cd7f4274efdbf3e7a75b0738d26&csf=1&web=1&e=zxn8TE.

Team 4 (Virtual): Echoes of Encounters.

Planned Materials:

A curated selection of digitised glass slides and composite artefacts depicting intersections of cultures across time: hybrid temple architectures, Roman-Egyptian sculptures, Greco-Islamic medical illustrations, and fictionalised reconstructions of intercultural exchange. Several slides suggest moments of transmission, adaptation, or hybridisation -such as Vesalius' drawings influenced by Islamic anatomical knowledge, or archaeological fragments showing stylistic fusion between Mediterranean civilisations (*KU Leuven Workshop -Storytelling*; *Team4_EchoesOfEncounter.docx* at: https://ujchmura.sharepoint.com/:f:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials?csf=1&web=1&e=Hnf4jz).

Original Narrative Concept (based on *KU Leuven Workshop -Storytelling*):

This scenario explored what happens when cultures meet intellectually, symbolically, and materially. Rather than focusing solely on individual artefacts, Team 4 sought to bring to life the *encounter* itself. Central questions included: *What if two cultures met in a virtual space for the first time? Could Vesalius debate with an embalmer? How might a Roman architect and a Tang dynasty engineer discuss form and function?*

Participants were invited to design immersive, dialogic narratives that transcended temporal and geographic borders. The VR environment became a speculative agora, where historical figures or their epistemic legacies could "speak" across civilisations. The concept moved fluidly between real objects and imagined interactions, emphasising syncretism, influence, and shared symbolic systems.

Workshop Execution and Adaptation:

Team 4 interpreted the prompt not as a linear reconstruction of a historical event, but as a dynamic space of creative cultural synthesis. Workshop participants interacted with artefacts depicting syncretic aesthetics (e.g., Greco-Egyptian temples), while also generating speculative scenes of intercultural dialogue. They reimagined the virtual museum as a *threshold space* for cultural memory, where timelines are porous and meaning is co-constructed. Emphasis was placed on the affective dimension of intercultural transmission -the emotional tone of cultural exchange, whether curiosity, reverence, misunderstanding, or wonder. Some teams used fictionalised avatars of scholars or artists to represent traditions in conversation, while others embedded “what if” speculative moments into object-based interaction flows.

Key Features:

- Intercultural dialogue simulation, where historical figures or traditions meet in virtual space to discuss, debate, or co-create.
- Narrative layering, combining visual evidence (slides, artefacts) with speculative reconstructions of encounters.
- Dynamic object interpretation, allowing artefacts to be seen from multiple civilisational perspectives (e.g. anatomical vs ritual vs architectural).

Identified Gaps:

- Absence of predefined dialogue scaffolding, limiting users' ability to script or branch intercultural interactions in real time.
- Lack of automated cultural referencing, such as annotations revealing hybrid styles, intellectual borrowings, or translational motifs.
- Limited modelling of emotional dynamics, such as tension, empathy, or ethical disagreement between traditions.

User Roles (narrative-based):

As in Teams 1-3, user roles in Team 4 were not professional identities, but speculative, narrative personas designed to test the interpretive and interactive potential of cross-cultural scenarios. Drawing on the plan's suggestion (*"What if Vesalius met an embalmer?"*), the roles focused on performative dialogue and cultural positioning.

Roles included:

- The Anatomist-Scholar: Brings empirical, text-based traditions into dialogue; represents European scientific rationality shaped by intercultural antecedents.
- The Ritual Practitioner: Embodies situated, embodied knowledge of healing or sacred symbolism; brings intuitive and symbolic interpretation.
- The Architect-Historian: Interprets material culture and design as reflective of civilisational values; traces continuity and innovation across styles.
- The Mediator: Bridges traditions; contextualises conflicts and commonalities between knowledge systems; invites reflective spectatorship.

These narrative-based user roles were used to explore epistemic pluralism and simulate creative friction between historical perspectives. As noted in the plan, *"Participants can explore how virtual spaces amplify creative dialogue across time and place.". T*he following excerpt is taken from a plan, as well as actual material developed during a two-day workshop in Leuven. The workshop material is available at the following address https://ujchmura.sharepoint.com/:f:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.3UserStudy(M7-15)/Report%26Research/Workshop_materials?csf=1&web=1&e=NXlKRP.

Note on User Roles and Source Materials:

The user roles assigned in Teams 1-4 were designed as part of the preparatory work conducted by the KU Leuven team to facilitate immersive narrative testing during the workshop. These roles do not necessarily reflect the actual professional backgrounds of participants but were created to enable scenario-based exploration of intercultural and epistemic narratives. Additionally, the references to medical and anatomical materials in Team 2 are based strictly on the digitised resources and historical materials provided during the workshop sessions. This clarification ensures consistency and accuracy across all deliverables and aligns the terminology used for user roles and workshop content.

Table 6. Summary Table: Narrative Prototypes and User Roles in VR Storytelling.

Team	Materials	Narrative Focus	Key Features	User Roles (Narrative -based)	Identified Gaps
1 *Ancient Places, Living Heritage*	Archaeological slides (Palmyra, Baalbek, Jerash, Dendera); excavation images, floor plans	*"Seeing as others saw"* - interpreting historical sites from diverse social and temporal perspectives	Role-swapping across historical personas; layered visual interpretation; contextual timeline	Archivist, Photographer, Historian, Local Inhabitant	Limited multi-perspective switching; no dynamic annotation
2 *Anatomy of Discovery*	Vesalius' anatomical drawings; digitised mummified bodies; early medical illustrations	*"Unfolding the Body"* - reimagining anatomical visualisation through layered, affective VR interaction	Layer-based anatomy interaction; timeline narrative; speculative authorship module	Anatomist, Medical Student, Historian of Medicine, Speculative Scientist	Incomplete 3D modelling; limited collaborative tools; no gender-sensitive narrative scaffolding
3 *Reimagining Ancient Storytelling*	Glass slides with murals, reliefs, mythological scenes (Roman, Egyptian); narrative fragments	*"Voyages through Shadows and Fragments"* - creating nonlinear, participatory visual narratives	Projection mapping; dynamic light and shadow; narrative layering; perspective shifting	Story Weaver, Shadow Caster, Memory Keeper, Light Architect	No real-time collaborative editing; limited emotional scaffolding; absence of frameless exploration tools
4 *Echoes of Encounters (Virtual)*	Glass slides and composite artefacts showing cross-cultural exchange (e.g. Roman-Egyptian, Greco-Islamic); fictionalised encounters	*"When Cultures Meet"* - speculative dialogue and visual hybridity in VR	Intercultural dialogue simulation; dynamic object interpretation; narrative blending	Anatomist-Scholar, Ritual Practitioner, Architect-Historian, Mediator	No dialogue scaffolding; weak cultural referencing; limited modelling of emotional dynamics

This summary table integrates both the planned narrative scenarios outlined in the KU Leuven Workshop -Storytelling document and the actual activities undertaken during the participatory sessions implemented in different documents available at:

https://ujchmura.sharepoint.com/:w:/r/teams/impulsegeneral_group/_layouts/15/Doc.aspx?sourcedoc=%7BE6ABD907-DD51-4FFB-AF10-03053278F250%7D&file=KU%20Leuven%20Workshop%20-%20Storytelling.docx&action=default&mobileredirect=true.

The user roles presented were conceptualised as part of the workshop facilitation strategy and should be interpreted as narrative constructs rather than direct reflections of participants' real-world professions. The identified gaps reflect both technical limitations observed during the sessions and conceptual improvements proposed by participants. Key Insights and Design Recommendations

Key insights and design recommendation.

The following key insights and design recommendations synthesise the findings from the workshop, focusing on the collaborative features, narrative depth, and other essential elements of the immersive environments developed by the teams. These recommendations have been derived from the comparative analysis of the user responses, the core features identified, and the gaps that emerged during the workshop. They are intended to guide the next phases of development and ensure that the prototype better aligns with user expectations and requirements.

Collaborative Features.

A fundamental insight from all teams is the importance of collaborative features for co-creation and role-based interaction. Users across all groups highlighted the need for tools that enable collective narrative-building and interpretation. This feedback suggests that real-time multi-user functionality should be prioritised in future iterations to facilitate co-narration, shared engagement, and collaborative exploration of the virtual environments. The ability to work together as a group will enhance the immersive experience and provide users with a sense of collective agency in shaping the narratives.

Narrative Depth.

Users from all groups expressed a shared desire for increased narrative depth, which can be achieved by offering multiple layers of meaning, such as historical context, cultural interpretation, and creative expression. Participants want the system to support non-linear storytelling that allows for flexible and multifaceted narrative exploration. This feature will help users engage with content in a more meaningful way, enabling them to interact with stories from diverse perspectives. Incorporating tools that support branching narratives or user-driven content exploration will further enhance the immersive experience.

Expressive Affordances.

Users highlighted the importance of expressive affordances, such as avatar customisation and multi-sensory feedback (e.g., spatial sound), to deepen emotional

engagement and embodiment within virtual environments. These features will enable users to feel more connected to the virtual content, facilitating a more immersive experience. Future development should explore the integration of these features to enable users to fully embody their roles within the immersive world, further enhancing their sense of presence and interaction with the content.

Ethical Considerations for G3.

Ethical considerations, especially for G3 (cultural heritage professionals), were identified as crucial for the platform's success. G3 participants emphasized the need for responsible representation, metadata integration, and provenance tracking to ensure the integrity and authenticity of cultural heritage experiences. As these professionals work with sensitive cultural data, it is essential to provide accurate, reliable, and ethical representations within the platform. Future iterations of the system should incorporate robust provenance tracking systems, detailed metadata, and guidelines for ethical representation to foster trust and reliability in virtual heritage experiences.

8.1.8 Leuven Workshop UX Survey: Analysis and Findings.

The UX survey was conducted during the Leuven workshop to evaluate the user experience (UX) of the IMPULSE VR prototype. The survey aimed to capture participant feedback regarding the usability of the platform, technical issues encountered, and user expectations for future functionalities. The questionnaire was designed to provide both quantitative data (through Likert scale questions) and qualitative data (through open-ended responses), allowing for an in-depth understanding of the users' experiences and challenges.

The survey results are based on the feedback from the participants who tested the prototype, with a focus on identifying:

- Usability issues and challenges faced by participants.
- Expectations for additional features and missing functionalities.
- Meta-level reflections and experiential insights shared by users during the testing.

The survey included both closed-ended and open-ended questions:

1. Quantitative Section:
    a. Likert scale questions to assess the platform's usability, intuitiveness, and engagement.
    b. These questions focused on areas like ease of navigation, satisfaction with the interface, system responsiveness, and overall user engagement.
2. Qualitative Section:
    a. Open-ended questions allowed participants to provide detailed feedback on specific issues encountered, including:
        i. Problem description: Where users could describe any problems they faced during interaction.

ii. Wanted functionalities: A section where participants suggested desired features or improvements.
iii. Additional comments: A final section for users to offer further insights or reflections on their experience with the platform.

The primary aim of the UX survey conducted during the Leuven workshop was to gather user feedback on the IMPULSE VR prototype. The survey targeted key usability aspects and user experience elements, specifically focusing on usability issues, user expectations, and desired functionalities. The survey also explored meta-level reflections regarding the system's design and overall user experience.

Objective of the Questionnaire:

The questionnaire was designed to achieve two primary objectives: first, to ascertain users' expectations, challenges, and experiences with immersive cultural heritage environments, and second, to explore how these environments can be adapted to meet diverse user needs. It consisted of both closed and open-ended questions, aimed at gathering insights into usability, content engagement, emotional response, and potential barriers to interaction.

The overarching goal of the questionnaire was two-fold: to provide a comprehensive understanding of users' perceptions and to gather valuable data for the refinement of the prototype. Aligning these objectives ensured a unified research agenda, facilitating a more holistic analysis. This approach enables the findings to directly contribute to improving the user experience and guiding the platform's development.

This survey complements the quantitative data and thematic coding from the structured questions, offering additional insights into user experience through open-ended responses. The data for thematic analysis was derived from three open-ended questions embedded in the user testing form:

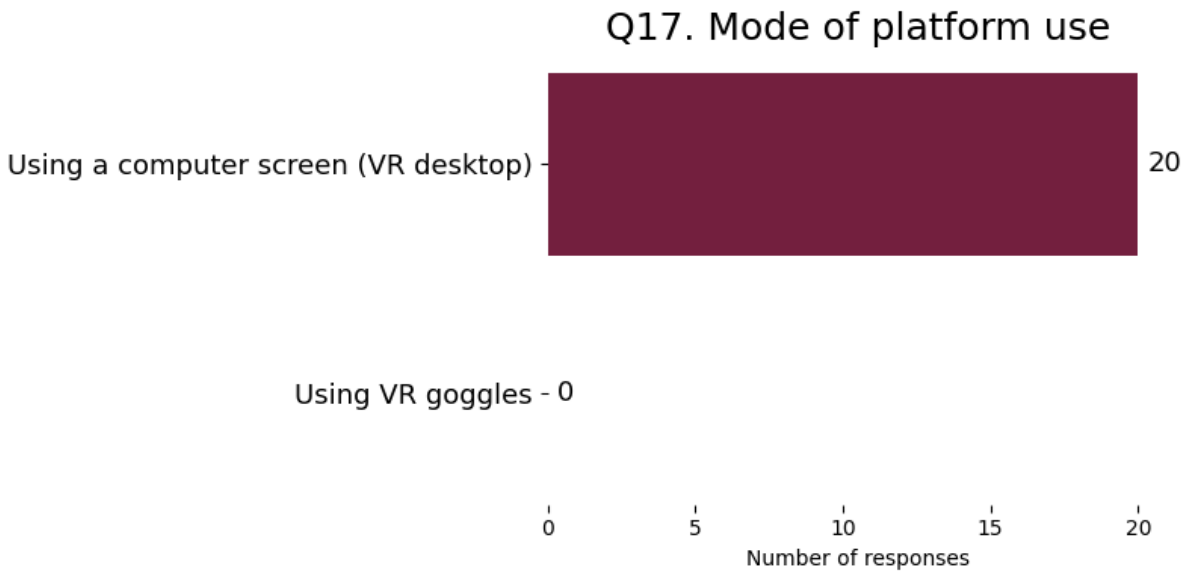
1. Problem description -An open-text field where participants could describe any issues encountered during testing.
2. Wanted functionalities -A question asking for suggestions on desired features or improvements.
3. Additional comments -An optional space for further reflections or unsolicited feedback.

Out of 20 total participants, 17 provided substantive responses across these three fields, resulting in 23 unique open-ended statements that were carefully analysed.

According to responses to question Q17 (Fig.1), none of the participants experienced the platform using VR goggles. All respondents declared using the desktop VR version. However, this result should be interpreted with caution. The questionnaire did not offer alternative response options, despite the fact that unexpected and significant technical issues limited access to the platform. As a result, some participants were only able

to experience the platform through a projector-based presentation, while others, those who managed to log in, interacted with the platform via their personal computers.

Fig. 2. Mode of use of the platform (prototype).

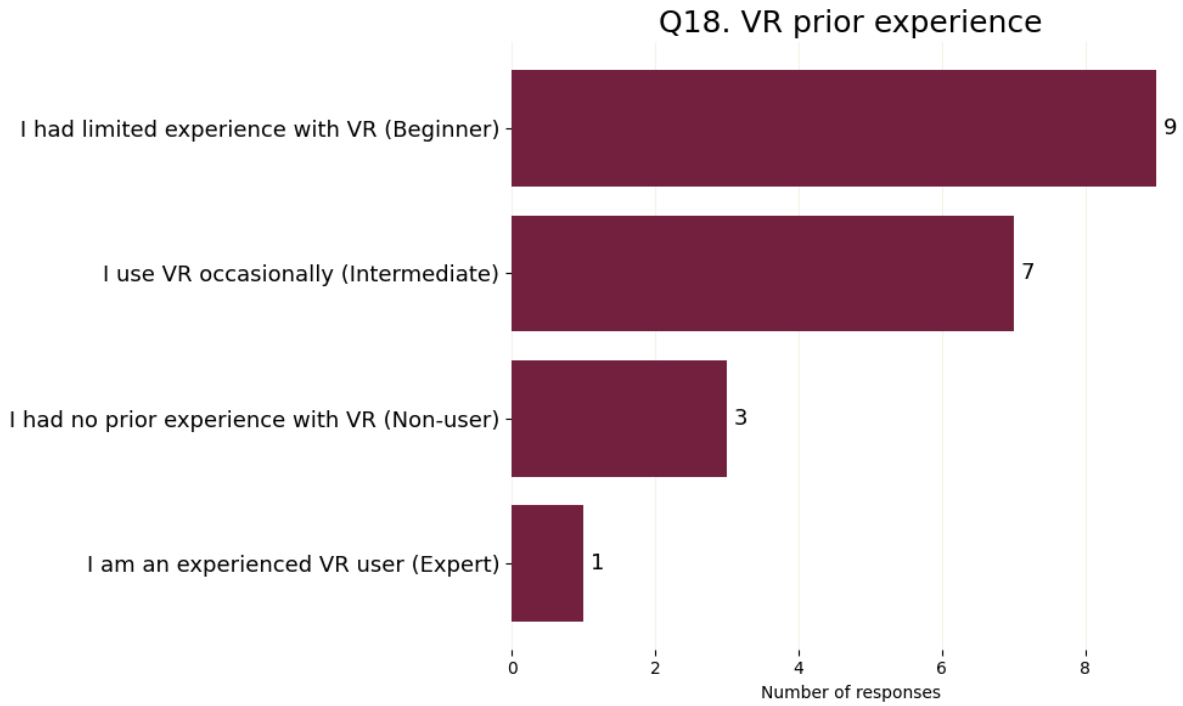


Responses to question Q18, which asked participants about their prior experience with virtual reality, indicate that the majority had limited or occasional exposure to VR:

- 9 respondents reported limited experience with VR (Beginner),
- 7 respondents selected I use VR occasionally (Intermediate),
- 3 respondents indicated no prior experience with VR (Non-user),
- Only 1 respondent identified as an experienced VR user (Expert).

These results suggest that most participants had little to moderate familiarity with VR technology prior to the test session. This limited background may have shaped how users approached the prototype and perceived its usability, especially in light of the technical difficulties encountered during testing.

Fig. 3. Users' prior VR experience.



Methodological approach for quantitative analysing closed-ended responses.

The analysis followed a multi-step procedure, outlined below to ensure clarity, transparency, and reproducibility of the quantitative processing of closed-ended survey data.

1. Data preparation and transformation:

- Survey responses were exported from Microsoft Forms into an Excel file.
- The Excel file was loaded into a dataframe using the *pandas* library in a Google Colab environment.
- Column headers, originally derived from full survey questions, were shortened for clarity and analytical consistency while maintaining semantic accuracy.
- Column headers were also translated from Polish (the default language of the university's Microsoft Forms account) into English to facilitate presentation to an international audience.
- Empty columns such as *Email address* and *Name*, automatically generated by Forms but unused in the survey, were removed.
- Multiple-choice responses (e.g., to questions such as *Difficulties importing 2D content*, *Changing size difficulties*, *Movement difficulties*, *Difficulties aspects*, and *Wanted functionalities*) were split into separate entries while retaining record IDs. These were stored in separate sheets within the same Excel file.

2. Preparing for visualization:

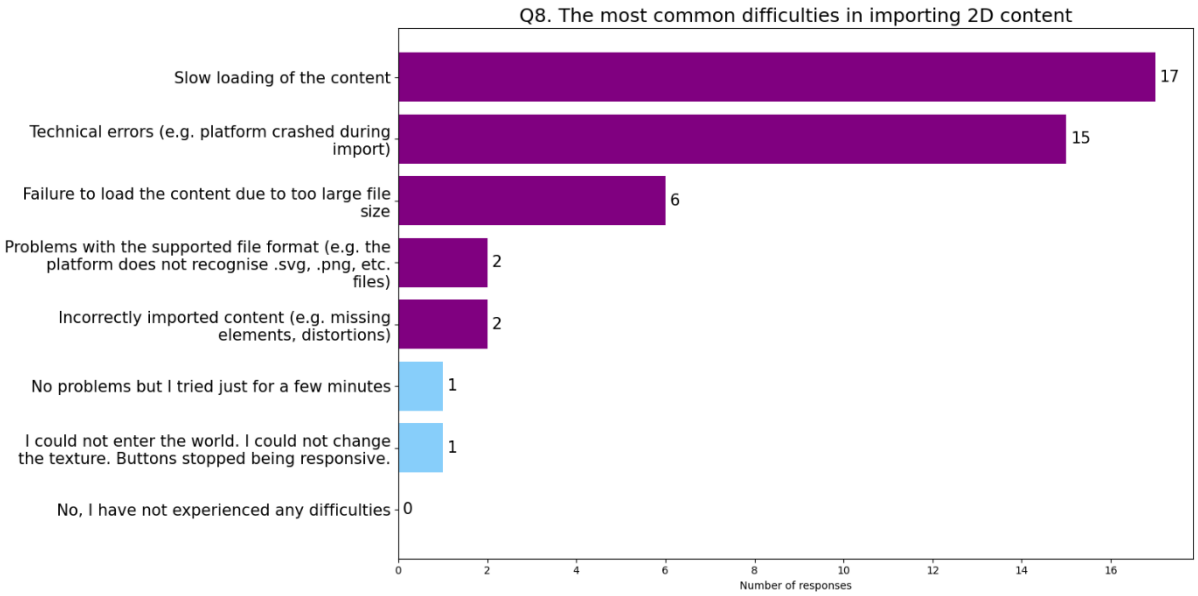
- The number of responses for each answer option was counted.
- All possible response options for each question were re-imported to ensure that even unselected answers (with zero responses) would be included in visualizations.
- For questions using a 7-point scale to evaluate selected attributes, both the distribution of responses and the average deviation from the neutral midpoint (value 4) were calculated and visualized.

3. Visualization:

- Visualizations were created using the matplotlib library.
- Each graph included clearly labelled axes, informative titles, data labels, and a layout designed for ease of interpretation.
- All charts were generated in Google Colab and exported in PNG format.

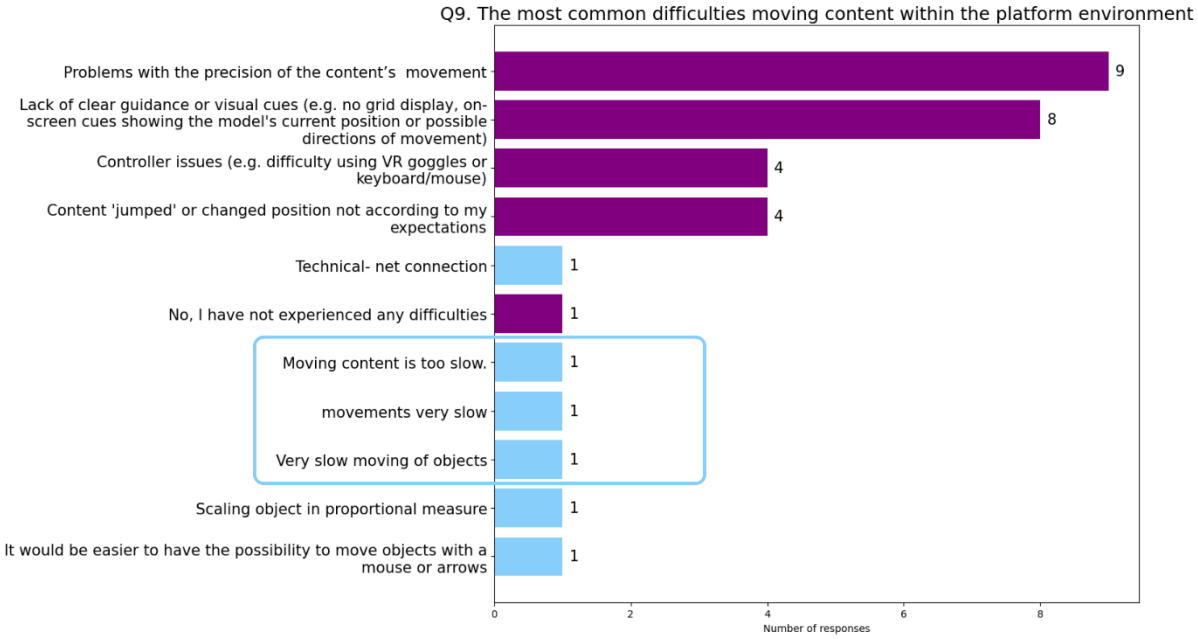
The responses are presented below, grouped by individual survey questions. Answers that respondents entered themselves after selecting the *"Other"* option are marked in blue.

Fig. 4. The most common difficulties with the import of 3D models.



The analysis of responses to question Q8 indicates that the most frequently reported issues when importing 2D content were slow content loading (reported by 17 out of 20 respondents) and technical problems with the platform (reported by 15 out of 20 respondents).

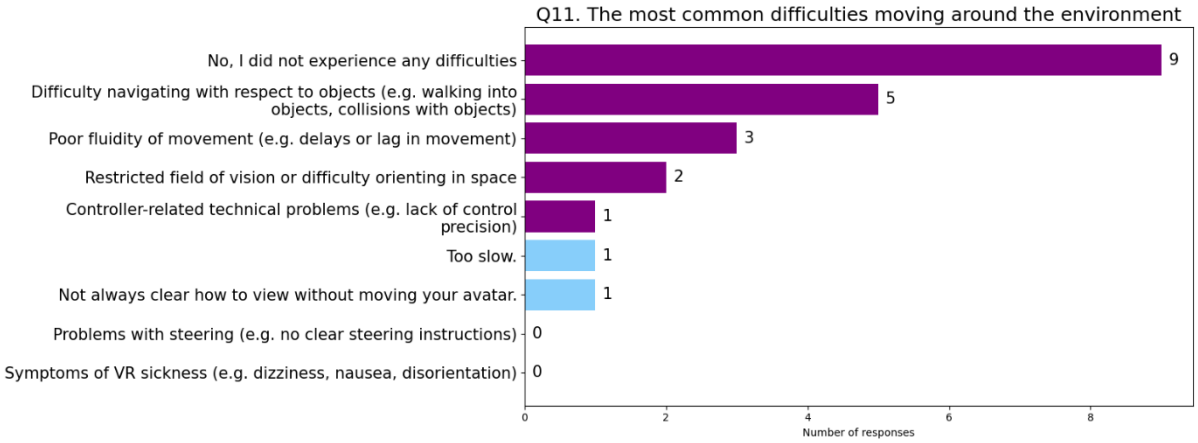
Fig. 5. Most frequent difficulties in moving content with platform landscape.



Issues related to the platform's slow performance were also noted by respondents answering question Q9, which addressed difficulties with moving content within the environment. Three participants chose to highlight this problem by entering it manually in the text field provided under the *"Other"* option.

The most frequently reported difficulties in this category (Q9) concerned the precision of content movement (reported by 9 out of 20 respondents) and the lack of guidance on the direction in which content should be moved (8 out of 20). Additional challenges included problems with controlling content using the keyboard (4 out of 20), and a suggestion that moving objects with a computer mouse or arrow keys would be more intuitive (1 out of 20). Unpredictable behaviour of objects was also mentioned (4 out of 20). Moreover, individual responses pointed to technical issues such as unstable internet connection and difficulties with proportionally resizing objects. One participant reported no difficulties related to the aspects addressed in Q9.

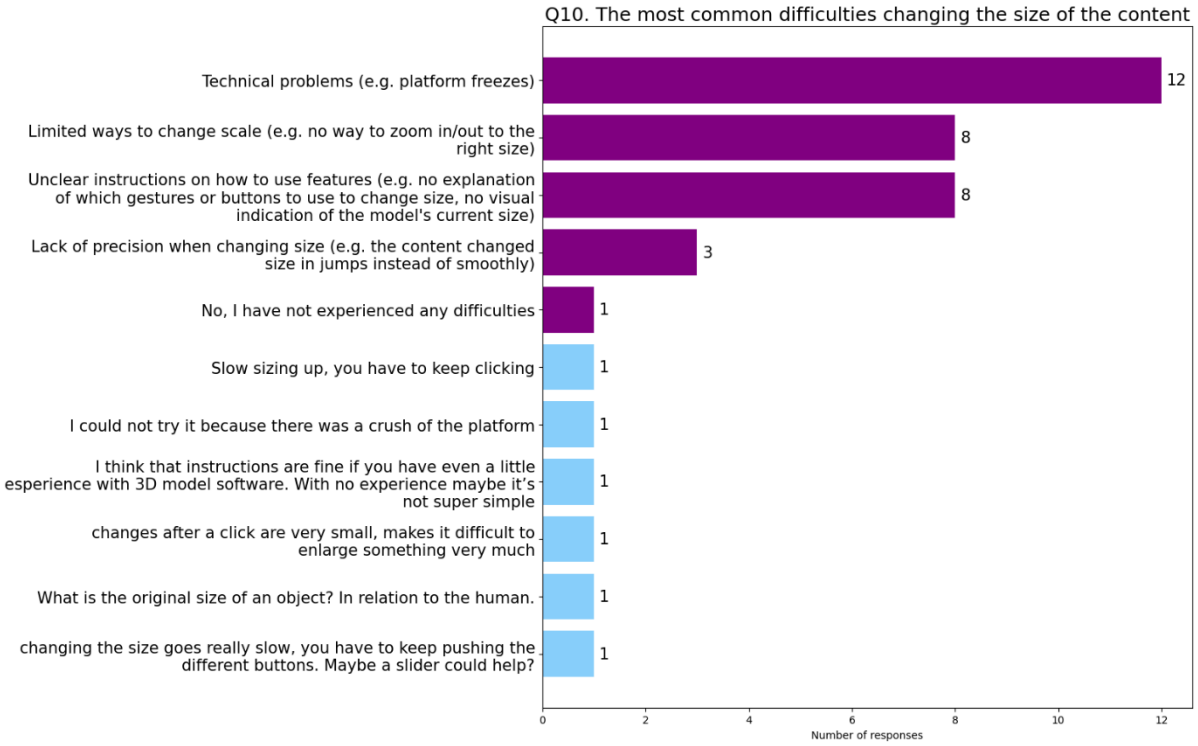
Fig. 6. The most common problems with platform movement.



In response to question Q11, the majority of participants reported no difficulties with navigating the platform. However, this result should be interpreted with caution due to technical issues that significantly limited free access to the platform. Similar caution is advised when interpreting the lack of responses indicating difficulties with controls. The absence of reports related to VR sickness should also be considered in context, as none of the participants had the opportunity to experience the platform using VR headsets.

The most frequently reported issues related to Q11 included problems with navigation in relation to objects (5 out of 20), poor fluidity of movement (3 out of 20), and overly slow movement speed (1 out of 20), as well as a limited field of view or difficulty orienting in space (2 out of 20), and once again, issues with movement precision (1 out of 20).

Fig. 7. Most common difficulties in resizing content.

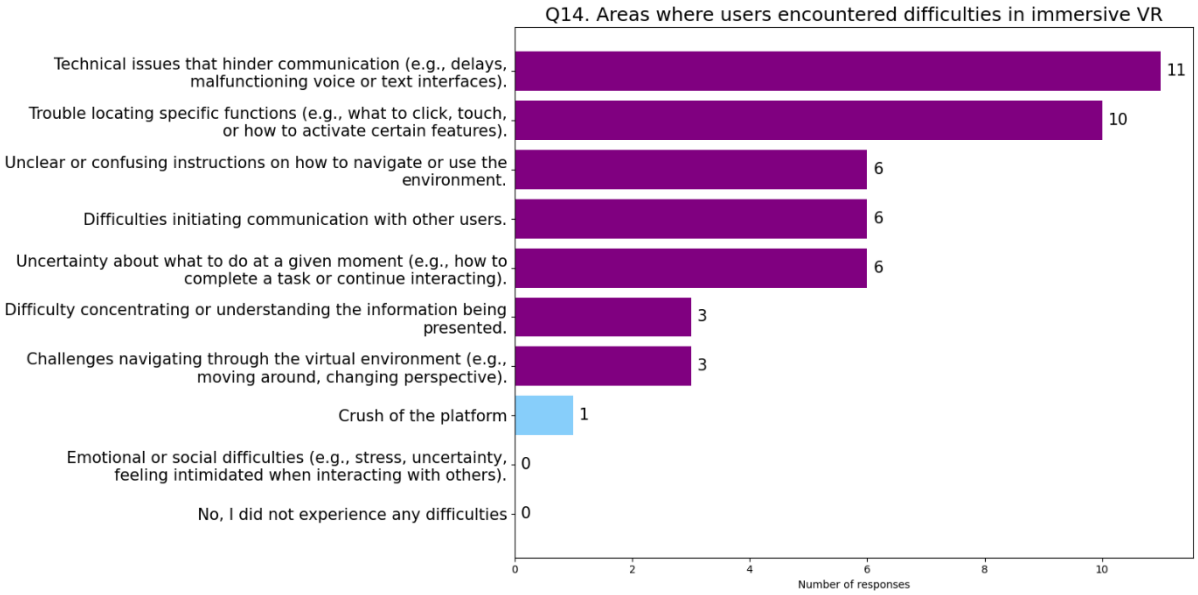


Regarding difficulties related to resizing content (Q10), the most frequently reported issues were technical problems with the platform (12 out of 20 respondents), limited options for adjusting content size (8 out of 20), and unclear instructions on how to use specific functionalities (8 out of 20).

Among the open-text responses, participants suggested two improvements: first, a resizing slider to make it easier to adjust the size of the object; and second, a way to indicate the original size of the object in comparison to the average size of a human, represented by the avatar. However, this latter option was not feasible during testing in Leuven due to the content upload procedure adopted there: participants selected a block from a set of basic 3D shapes, which could then be textured with 2D content. As a result, it was not possible to upload 2D content in its original dimensions relative to the avatar's size.

The suggestion regarding the original size of the object highlights a piece of information that was considered important by the participants. Therefore, this feature should be considered in future development work or recommendations for cultural institutions creating their own platforms and engaging in digitisation efforts.

Fig. 8. Areas where users have struggled with immersive VR.

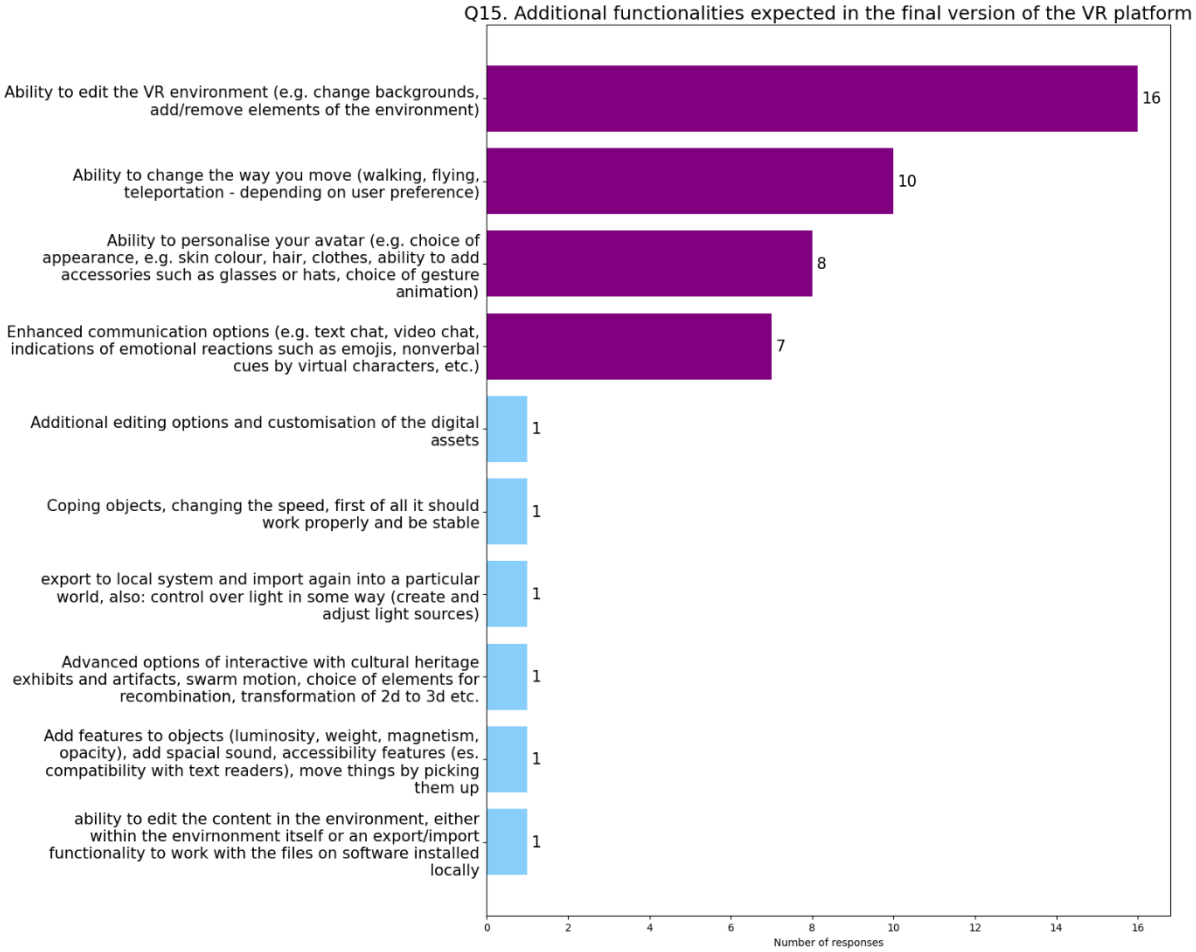


Question Q14 allowed respondents to provide a summary indication of the aspects of interaction with the prototype in which they experienced difficulties.

The most frequently reported issues included technical problems (11 out of 20, plus 1 additional response under the *"Other"* option), difficulties in locating specific functions (e.g., knowing what to click on) (10 out of 20), unclear instructions and uncertainty about what actions to take to achieve a given outcome (6 out of 20 each), as well as difficulties establishing communication with other users (6 out of 20).

No emotional or social difficulties were reported. However, it should be noted that the version of the prototype tested in Leuven lacked extensive functionalities in this area -participants could see other avatars (when the platform was functioning properly) and potentially greet them by waving their avatar's hand, but no more advanced interaction features were available.

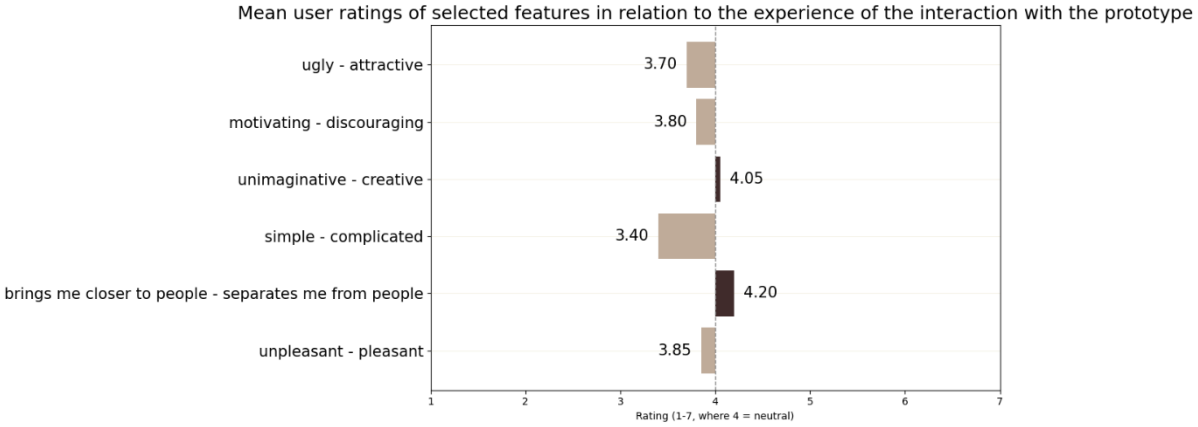
Fig. 9. Expectations for additional functionalities in the final version of the VR platform.



In response to the question about expected functionalities that, according to participants, should be included in the final version of the platform (Q15), as many as 6 respondents chose to provide their own suggestions. These open-text answers form the basis for the thematic analysis presented below.

Among the closed-ended options, the most frequently requested features included the ability to edit the VR environment (16 out of 20), the option to change the mode of movement (10 out of 20), avatar personalization (8 out of 20), and enhanced means of interacting with other users (7 out of 20).

Fig. 10. Average user ratings of selected features related to prototype interaction experience.



In relation to the evaluation of selected attributes, the average ratings presented in the figure reveal how participants positioned their impressions along various bipolar scales (1-7, where 4 represents a neutral midpoint).

Overall, the ratings are relatively close to the neutral midpoint (4.0), indicating a generally balanced or ambivalent perception of the prototype. The most positively evaluated attribute was simplicity (simple -complicated, M = 3.40), showing the greatest deviation from neutrality in a favourable direction. Conversely, the lowest-rated aspect was visual aesthetics (ugly -attractive, M = 3.70), suggesting a slightly negative impression in terms of appearance. Interestingly, both the dimension motivating -discouraging and brings me closer to people -separates me from people show a deviation of 0.2 points from the neutral value, but in opposite directions -reflecting subtle yet opposite tendencies in how participants perceived engagement and social connection.

The six charts below illustrate how participants rated the prototype across bipolar adjective pairs using a 7-point Likert scale (where 4 = neutral). The results reveal relatively symmetric distributions centred around the neutral point, though some dimensions stand out with slight shifts in positive or negative directions.

- Simplicity vs. complexity: The dimension simple -complicated was rated most favourably, with a noticeable concentration of responses toward the “simple” end of the scale (mean = 3.40), indicating that users generally perceived the interface as easy to use.
- Visual attractiveness: In the ugly -attractive dimension, the distribution was more varied, though skewed slightly toward the negative side (mean = 3.70). Ten participants chose the neutral midpoint, while several leaned toward the "ugly" end, suggesting mixed impressions regarding the platform's aesthetics.
- Social connectedness: Ratings for brings me closer to people -separates me from people were highly concentrated at the neutral point (14 out of 20 selected 4), with minimal variation (mean = 4.20). This indicates a rather balanced but

inconclusive perception of social interaction, with a stronger opinion in separating direction.

- Pleasantness: The dimension unpleasant -pleasant also centred strongly around the neutral point (mean = 3.85), with 12 neutral responses. This balanced distribution suggests a generally stable, though somewhat muted, affective reception.
- Motivation: In the motivating -discouraging dimension (mean = 3.80), the distribution was more ambivalent, with responses spread across the entire scale -some users found the experience motivating (e.g., 5 responses at 2), while others reported it as highly discouraging (e.g., 2 at 6, 2 at 7). This points to notable individual differences in how the experience was perceived.
- Creativity: Ratings on the unimaginative -creative scale (mean = 4.05) showed a broad spread, with responses appearing at nearly every scale point. This dimension also reflects a highly ambivalent response pattern, suggesting a lack of clear consensus and varied user interpretations of the prototype's creative potential.

In summary, while most user opinions clustered around the neutral midpoint, a few dimensions stood out. Simplicity emerged as the most positively evaluated attribute, whereas visual attractiveness leaned slightly negative. The most balanced impressions were observed for pleasantness and social connectedness, whereas motivation and creativity showed more ambivalent distributions, highlighting divergent user experiences and preferences.

Fig. 11. Results of participants' evaluation of the simplicity of the prototype in pairs of bipolar adjectives using a 7-point Likert scale (where 4 = neutral).

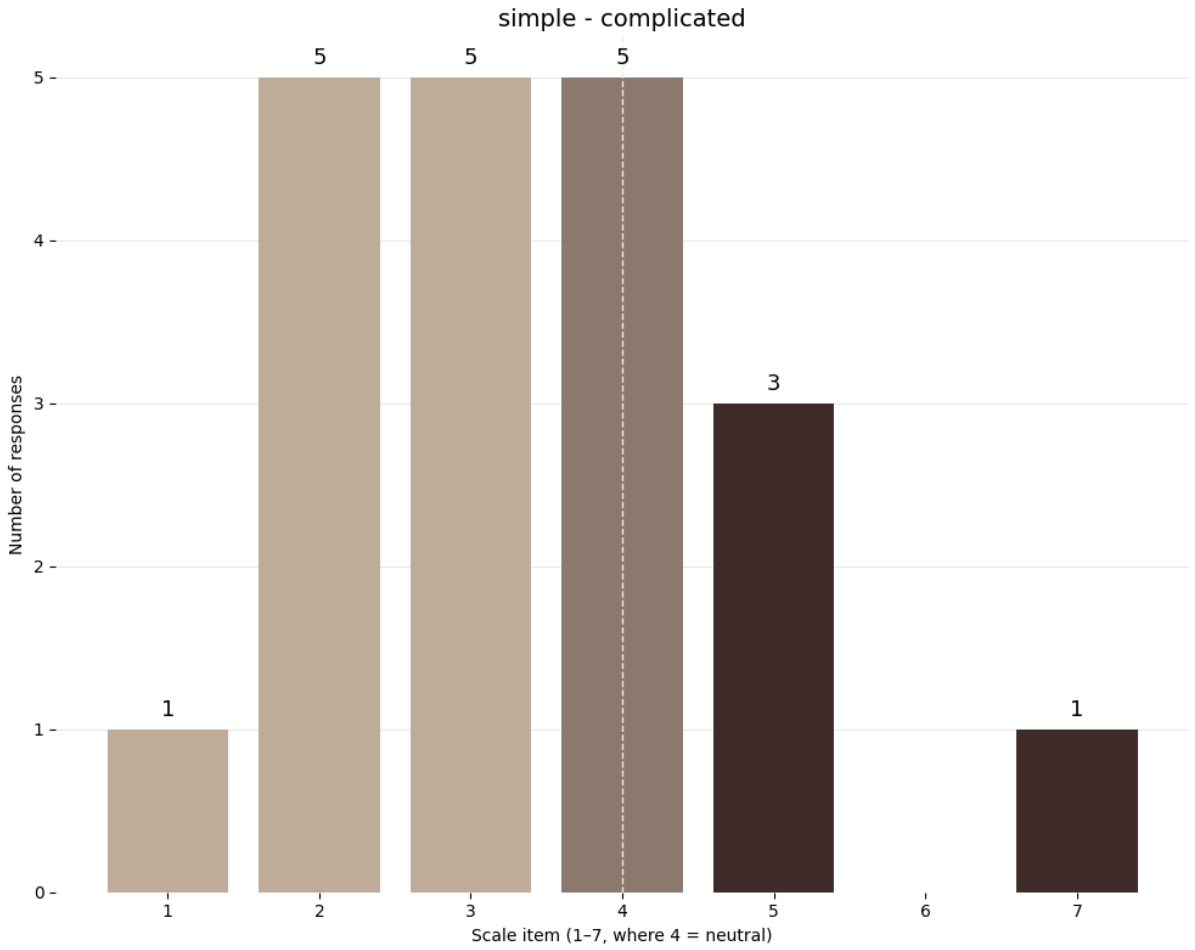


Fig. 12. Results of participants' rating of the attractiveness of the prototype in pairs of bipolar adjectives using a 7-point Likert scale (where 4 = neutral).

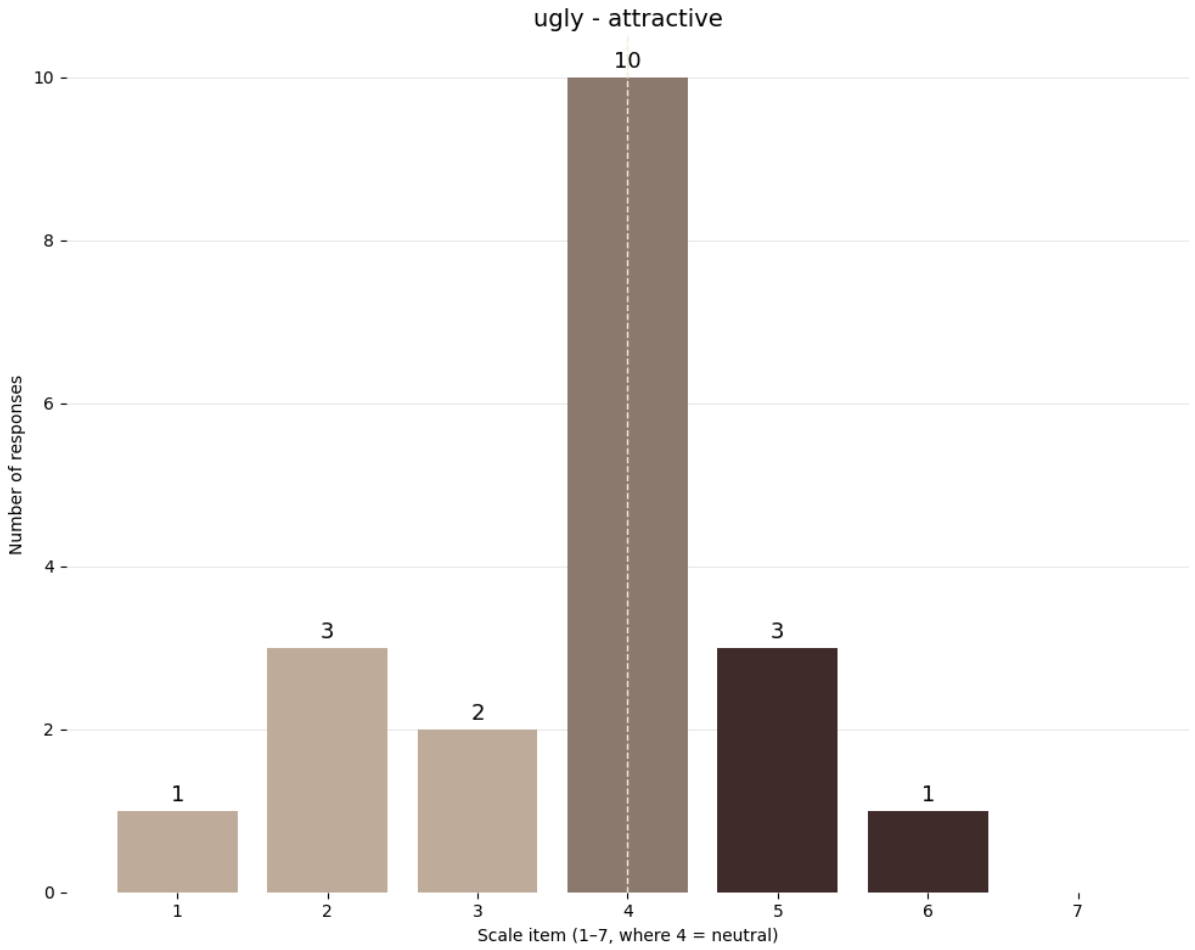


Fig. 13. Results of participants' evaluation of the social relatability of the prototype in pairs of bipolar adjectives using a 7-point Likert scale (where 4 = neutral).

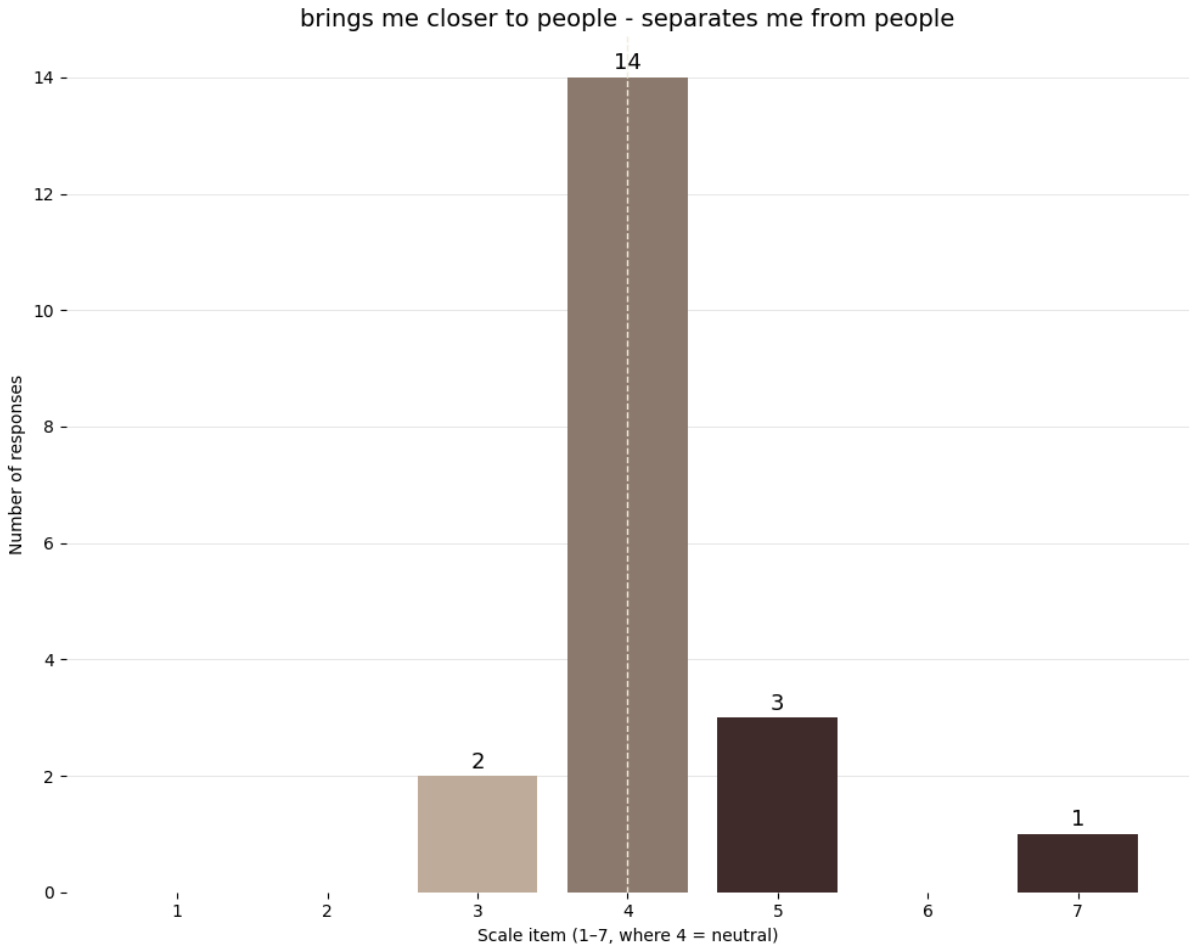


Fig. 14. Results of participants' rating of the prototype's sense of pleasure in pairs of bipolar adjectives using a 7-point Likert scale (where 4 = neutral).

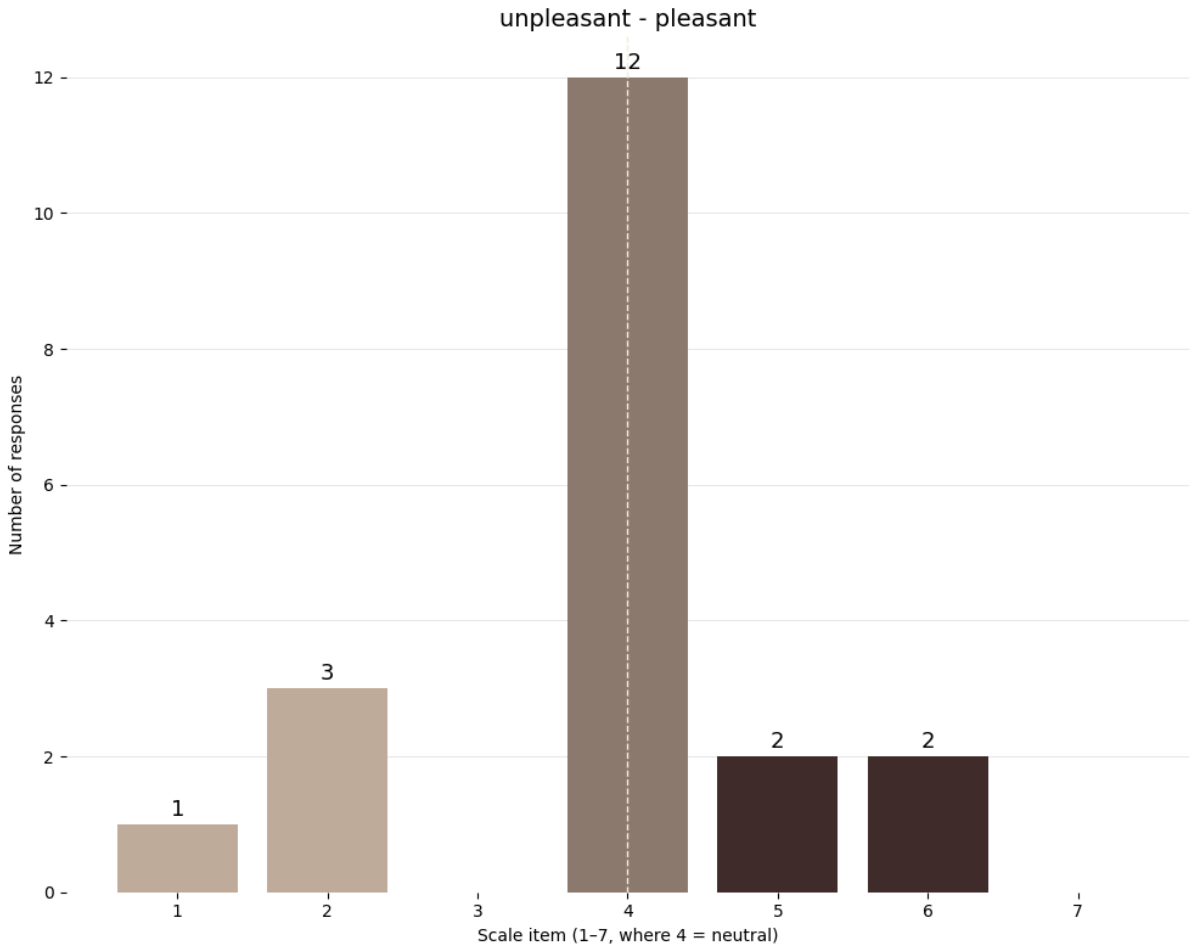


Fig. 15. Results of participants' rating of the prototype's sense of motivation in pairs of bipolar adjectives using a 7-point Likert scale (where 4 = neutral).

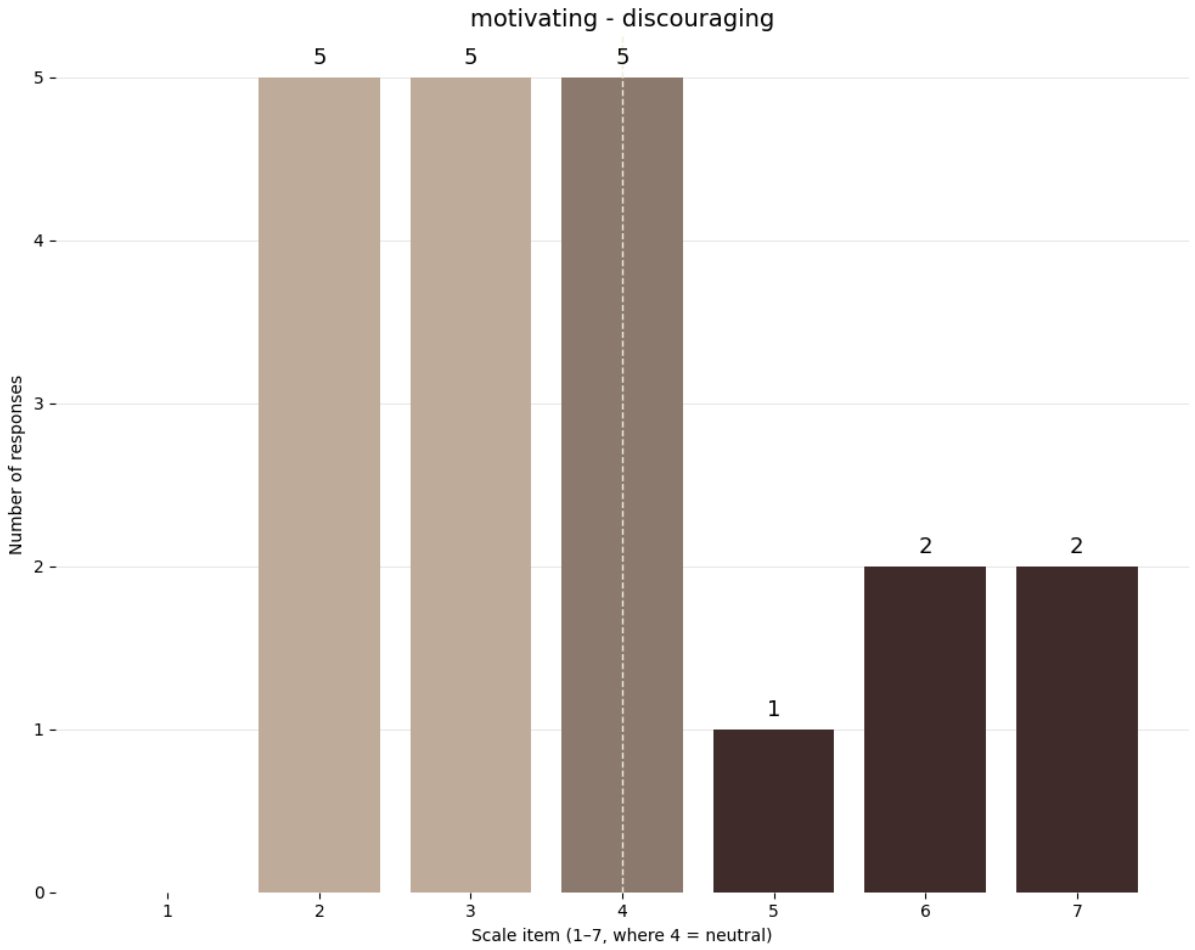
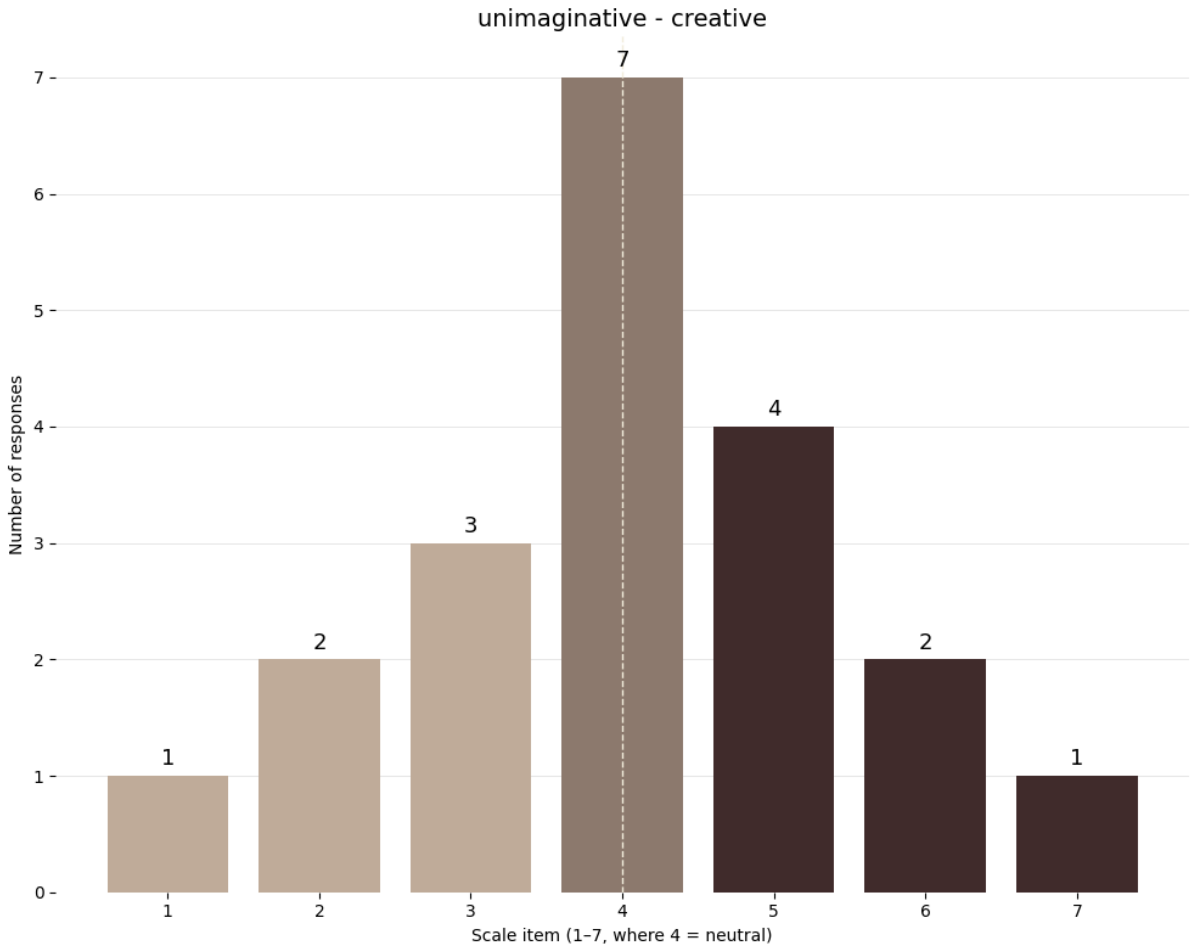
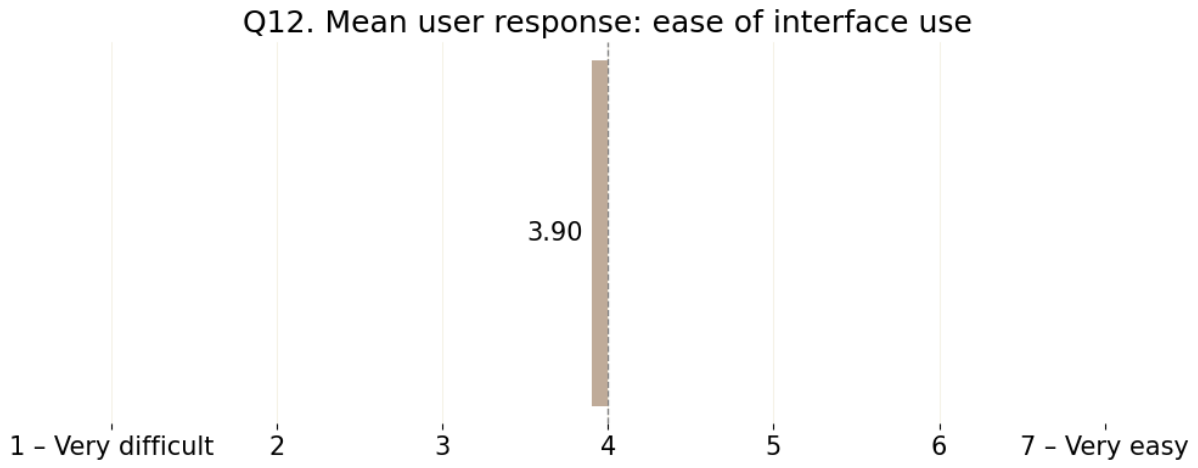


Fig. 16. Results of participants' rating of the sense of prototype creativity in pairs of bipolar adjectives using a 7-point Likert scale (where 4 = neutral).



The average user rating of the ease of interface use, as shown in answers for Q12, was 3.90 on a 7-point scale (where 1 = very difficult and 7 = very easy). This result is very close to the neutral midpoint (4.0), suggesting that participants overall perceived the interface as neither particularly easy nor particularly difficult to use. The nearly neutral average may reflect the mixed experiences reported in other parts of the survey, including technical issues or unclear instructions. While the interface was not rated as especially challenging, the score does not indicate a strong sense of usability either.

Fig. 17. Mean user reaction: Ease of use of the interface.



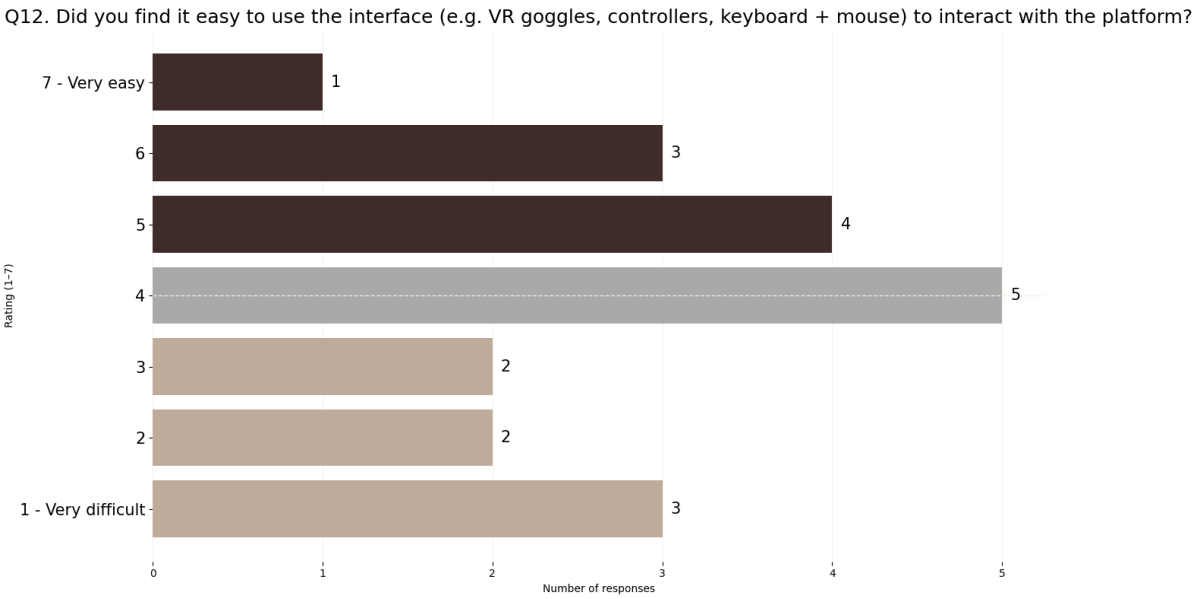
The horizontal bar chart illustrates the distribution of individual responses to question Q12, which asked participants how easy it was to use the interface (e.g., keyboard + mouse) to interact with the platform. Responses were given on a 7-point scale, where 1 indicated very difficult and 7 indicated very easy. It is important to note that both the prototype and the questionnaire were developed under the initial vision of WP2, with the intention to incorporate VR goggles and controllers for interaction. However, these devices were not available for use during the Leuven workshop, meaning participants interacted only with the alternative input methods (keyboard + mouse). The responses thus reflect this limitation, while future iterations of the platform are expected to fully integrate VR-based interactions as originally intended.

The results show a diverse range of experiences, with responses spread across the entire scale:

- 3 respondents selected the lowest score (1 -very difficult), indicating significant difficulty with interface use.
- 2 respondents chose each of the scores 2 and 3, reflecting moderate challenges.
- The neutral midpoint (4) was selected most frequently -by 5 respondents, suggesting an ambivalent or balanced perception of usability.
- On the positive side, 4 participants chose 5, 3 chose 6, and 1 chose the maximum score of 7.

This distribution suggests no clear consensus regarding ease of use. While some participants found the interface easy or very easy to operate, others experienced it as difficult or very difficult. The responses indicate a bimodal tendency, with a cluster of ratings around both lower and higher values, as well as a strong presence at the neutral midpoint -reflecting a high degree of variation in user experiences, potentially influenced by technical barriers or varying familiarity with interaction methods.

Fig. 18. The ease of use of the user interface for interaction with the platform.



Methodological approach for thematic analysis.

The analysis followed a qualitative content analysis approach, employing Braun & Clarke's thematic analysis (2006), adapted for human-computer interaction (HCI) and user experience (UX) studies. The methodological process involved the following steps:

1. **Data Preparation and Extraction**
   All responses from the three open-ended questions were extracted from the dataset. The responses were cleaned for duplicates and irrelevant blanks, then organised in a structured table. Each entry was linked to a respondent ID and the corresponding source question.
2. **Segmentation into Meaning Units**
   Each response was segmented into discrete meaning units, such as identifiable ideas, problems, or suggestions. For example, a compound response like *"platform crashed, and I couldn't test the collection"* was split into two distinct meaning units: (1) platform instability, (2) test process interruption.
3. **Open Coding.**
   The meaning units were coded using open coding techniques, where provisional labels were assigned to describe the core idea (e.g., *"crash at startup"*, *"lack of avatar editing"*, *"hard to resize objects"*). These codes were inductively generated from the data, without imposing predefined categories.
4. **Thematic Categorisation.**
   Related codes were grouped into thematic categories that formed higher-level clusters. For example, *"lack of precise placement"*, *"hard to scale objects"*,

and *"missing object alignment grid"* were grouped under the theme Spatial Manipulation Issues.

5. **Interpretation and Synthesis.**
   Themes were synthesised and interpreted based on their frequency, qualitative richness, and implications for design. Representative quotes were selected to illustrate each theme. The final synthesis includes both functional (usability-related) and affective (experiential and reflective) dimensions of feedback.

The following themes were identified based on the three open-ended questions:

A. User-Described Problems (Problem Description).

Key Themes (n = 7 responses):

- Critical system instability -Platform crashes preventing interaction (2 mentions).
- Failure in 2D/3D mapping -Distorted rendering of images on primitives (1 mention).
- Lack of precise manipulation tools -Difficulty setting or adjusting objects (1 mention).
- Experience-dependence of usability -Interface usability conditional on prior 3D knowledge (1 mention).
- Unavailable functions or navigation stages -Inability to access certain stages or actions (1 mention).

Example Quote: *"Mapping a 2D image onto a primitive wraps it in a weird way."*

Implication:
Participants need more predictable, stable, and user-friendly affordances for basic tasks like importing, scaling, and arranging digital assets. These findings suggest a need for improving system stability and object interaction tools.

B. Suggested features (desired functionality)

Key Themes (n = 10 responses):

- Environment editing and spatial control -Background modification, object addition/removal, spatial sound, lighting (4 mentions).
- Avatar personalisation -Editing visual features and gestures (2 mentions).
- Alternative movement styles -Walking, flying, teleportation (2 mentions).
- Enhanced communication tools -Chat, video, emotional cues (1 mention).
- Cultural object interactivity -Transforming 2D to 3D, recombining heritage elements (1 mention).

Example Quote: *"Ability to edit the VR environment (e.g., change backgrounds, add/remove elements of the environment)."*

Implication:
A modular system architecture is required to support multi-layered editing capabilities, avatar expression, and differentiated user pathways (e.g., exploration vs. curation). The integration of these features will enhance user control and flexibility.

C. Meta-level Reflections (Additional Comments).

Key Themes (n = 6 responses):

- Difficulty with object placement and scaling -Floor and tile components hard to arrange (2 mentions).
- Avatars require deeper personalisation -Current models insufficient (1 mention).
- Desire for platform transparency -Users want to know system requirements and limitations beforehand (1 mention).
- Short test session length -Limited exploration possibilities (1 mention).

Example Quote: *"Placement of tiles/floor pieces is hard to make good."*

Implication:
Beyond functionality, users expect stability, transparency, and expressive flexibility in the platform. Participants also indicated that perceived constraints on agency reduced their sense of usability.

Cross-cutting Insights and Recommendations.

From the triangulation of open-ended responses, the following cross-cutting design implications are proposed:

- Interactivity-first design: Empower users to modify and narrate within the environment, rather than just explore.
- Dual interface modes: Provide basic and advanced interface versions to accommodate different levels of prior experience.
- Integrated onboarding: Introduce walkthroughs that explain core interactions and provide access to real-time guidance for new users.
- Stability over complexity: Prioritise a robust core experience before layering more advanced editing and interaction features.

This thematic content analysis highlights several key areas for improvement in the IMPULSE VR prototype. Technical issues related to system stability and manipulation tools were the primary concerns raised by users. Additionally, there was significant interest in enhancing user expression through avatar personalisation, environment editing, and advanced movement styles. Finally, users emphasised the importance of platform transparency and user guidance in future iterations. The feedback from the survey directly informs the ongoing UX design process and

provides critical insights into the user needs and expectations that will guide the next steps in the IMPULSE project.

The Leuven UX survey provided crucial insights into the usability and engagement of the IMPULSE VR prototype. The feedback revealed a strong interest in the creative and educational potential of the platform, despite the significant technical barriers. The key challenges identified were related to system stability, avatar customisation, metadata integration, and collaborative features. Moving forward, the next steps for WP2 and WP4 should focus on addressing these technical issues while enhancing the system's creative capabilities and user-centred design features.

Next Steps:

- WP2 should focus on improving platform stability and providing clearer onboarding instructions to guide new users.
- WP2 should prioritise the development of customisable avatars, enhanced movement styles, and modular environment editing tools.
- WP3 should work on ensuring metadata integration, responsible curation, and the ability for users to collaborate and co-curate within the platform.

8.2 Surveys (G1 & G2)

The general survey was designed for both current users and non-users (potential users) of the platform, with participants recruited from two target groups: G1 and G2. The questionnaire was developed based on the structure of the general survey outlined in Deliverable D1.1, but it was adapted in response to the conditions and insights gained during the Leuven test phase.

In particular, the following factors influenced the final shape of the survey:

- the absence of access to the VR platform prototype for respondents,
- the need for remote distribution, which required significant shortening of the questionnaire compared to the original version in D1.1,
- and the practical experience from the Leuven study, including observations about user needs and barriers.

Before launch, the survey underwent a pilot run during a UX research methodology class with students of the Electronic Information Processing program. We would like to extend our sincere thanks to the students for their valuable feedback, which helped refine and improve the final survey instrument.

The questionnaire was implemented using Microsoft Forms and prepared in two language versions: Polish and English. Each IMPULSE partner involved in distributing the survey within their institution or country was given the choice to either share the English version or develop a version in their preferred language.

The study was anonymous and voluntary, with participants informed that they could withdraw at any time without providing a reason. At the beginning of the form, participants were presented with a brief description of the study and the IMPULSE project, including a link to the project's official website for further details.

The final questionnaire consisted of 18 questions, structured into two separate response paths: one for VR users and one for non-users.

- The first question served to collect active, informed consent to participate in the survey.
- The second question asked whether the respondent had ever used VR, thereby directing them to the appropriate set of questions.

After this branching point:

- Non-users answered questions regarding barriers to VR use and factors that might encourage them to consider using VR in the future.
- VR users, on the other hand, responded to questions about:
    - frequency of use,
    - self-assessed proficiency,
    - devices and platforms used,
    - reasons for engaging with VR,
    - difficulties encountered,
    - types of experiences,
    - social interactions in VR,
    - expected functionalities,
    - interactions with virtual objects,
    - and their past experiences with digital cultural heritage in VR.

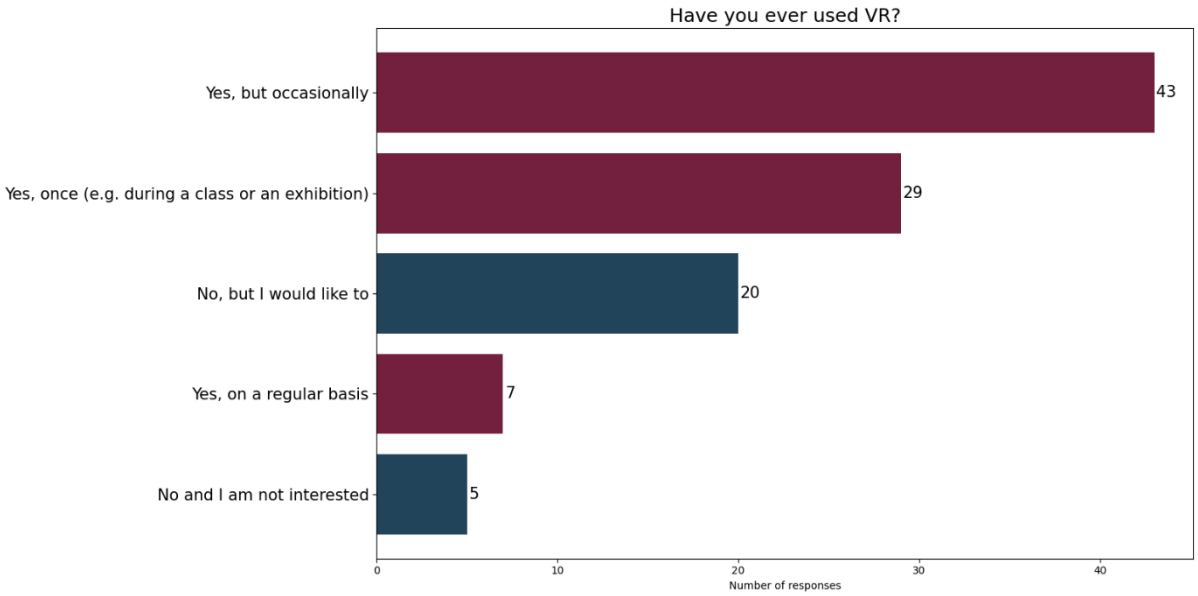
Both groups completed a shared demographic section, which included two brief items on academic status and field of study or specialization.

The questionnaire included multiple-choice items and three open-ended questions to allow for more detailed, qualitative input from participants.

The data analysis process followed a similar approach to the one used for the Leuven survey, combining both quantitative and qualitative methods. To prepare the dataset including the creation of headers, splitting of multiple-choice responses, translation into English, and merging responses from different language versions into a single file Python and Google Colab were used. A dedicated pipeline was developed in Google Colab to enable continuous updating of the dataset as new responses were submitted. Python was also used to analyse and visualise the responses to closed-ended questions. In the case of open-ended questions, a thematic analysis was conducted using MAXQDA.

As of April 11, 2025 (10:00 PM), a total of 109 responses had been collected -51 in the Polish version of the survey and 58 in the English version. Out of these, 104 participants provided informed consent to take part in the study.

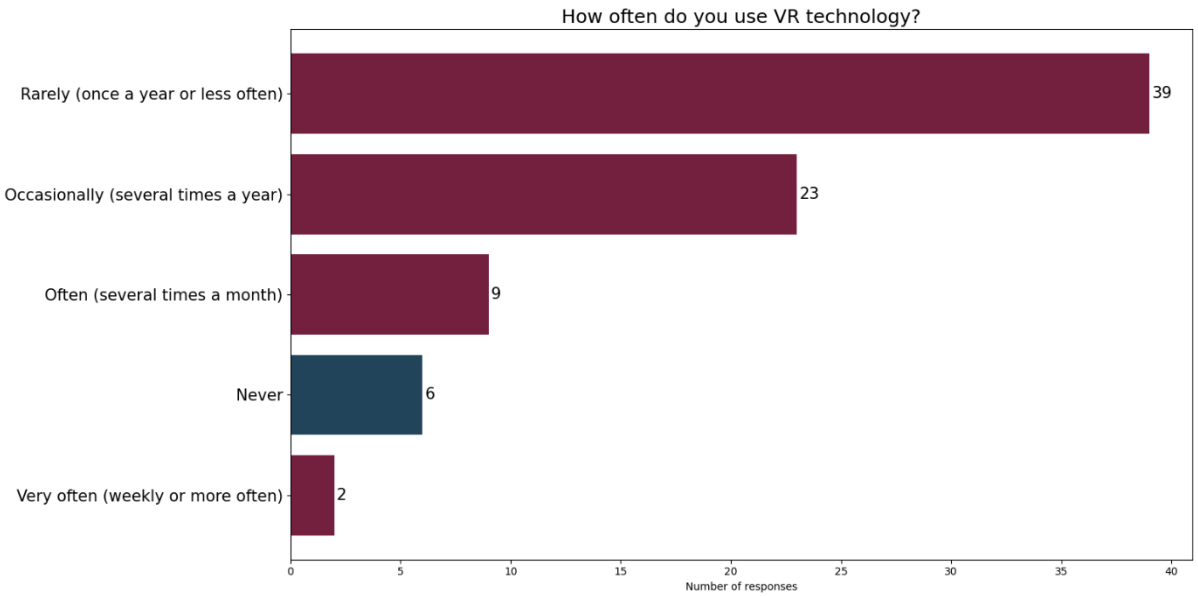
Fig. 19. The question of whether the users have ever used VR.



Among the respondents, 25 individuals identified as non-users of VR this includes those who selected *"No, but I would like to"* (20 responses) and *"No and I am not interested"* (5 responses). These responses are represented on the chart in a dark teal color, indicating participants with no prior hands-on experience with VR. The remaining respondents those who selected any of the *"Yes"* options can be considered VR users, although with varying levels of experience. Their answers are shown in burgundy on the chart, representing different levels of engagement with the technology, from a one-time use to regular usage.

A total of 43 respondents indicated that they had used VR occasionally, making this the most common experience level among participants. Additionally, 29 respondents stated they had used VR only once, for example during a class or an exhibition. These figures suggest that while a majority (79 participants) have had some interaction with VR, for most it remains an infrequent or experimental experience. Meanwhile, the 7 respondents who use VR on a regular basis form a small but significant group of more advanced users. Taken together, the results reflect a general openness to VR, though its regular use is still relatively rare.

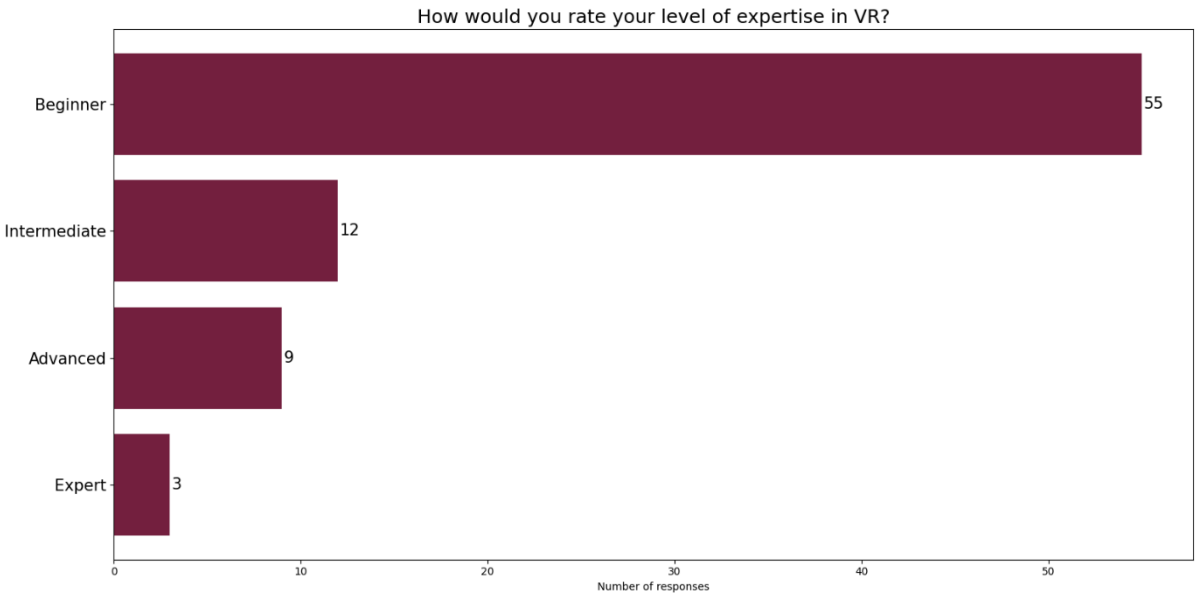
Fig. 20. Frequency of VR use.



Among respondents who identified as VR users, the vast majority reported using the technology infrequently. Specifically, 39 participants stated that they use VR *"Rarely (once a year or less often)"*, while 23 participants reported using it "*Occasionally (several times a year)"*. These two categories together account for over 80% of all VR users in the sample, indicating that for most participants, VR remains a sporadic activity rather than a routine part of their digital practices.

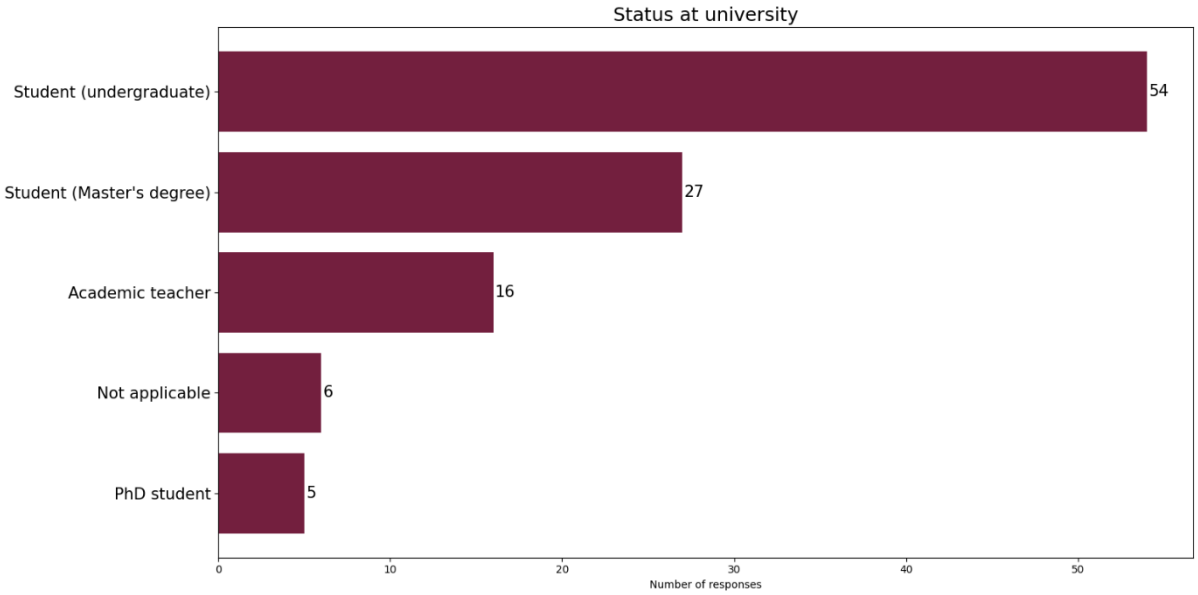
Only a small number of respondents use VR more regularly: 9 individuals reported using VR often (several times a month), and just 2 respondents stated they use it very often, defined here as weekly or more frequently. Additionally, 6 participants chose the option *"Never"*, confirming they had no experience with VR this group overlaps with the non-users identified in the previous question. Overall, the data suggest that while exposure to VR is relatively widespread, its adoption as a frequent or habitual tool is still limited.

Fig. 21. Question on the assessment of the level of expertise in the VR field.



The vast majority of respondents consider themselves beginners when it comes to VR technology. Specifically, 55 participants rated their level of expertise as *Beginner*, which clearly indicates that most users have limited experience and are likely in the early stages of exploring VR environments and tools. A smaller group of 12 participants identified themselves as having an *Intermediate* level of experience, followed by 9 respondents who rated their expertise as *Advanced*. Only 3 individuals considered themselves *Experts* in the use of VR.

Fig. 22. University status question.



The sample was predominantly composed of undergraduate students, who made up the largest group with 54 responses. This indicates that much of the feedback and data collected reflects the perspectives and experiences of individuals at an early stage in their academic journey. The second largest group consisted of master's degree students (27 responses), followed by *academic teachers*, who accounted for 16 responses.

Smaller numbers of respondents identified as *PhD students* (5) or selected the *"Not applicable"* category (6), suggesting limited participation from those outside traditional university structures or with unclear academic status. Overall, the distribution suggests that the majority of insights come from students, especially at the undergraduate and master's levels, which may influence the general level of VR familiarity and perceived expertise observed in the other survey results.

Illustration 1. A word cloud to visualise the general fields of study or disciplinary backgrounds declared by the participants in the survey.

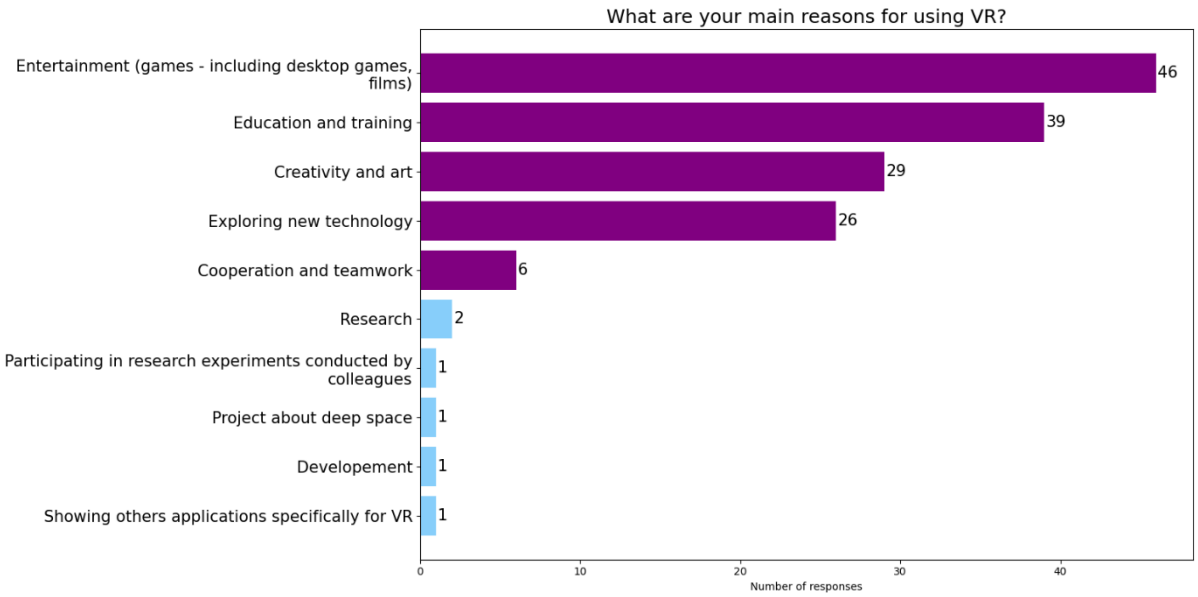
The word cloud visualizes the general fields of study or disciplinary backgrounds declared by survey participants, grouped into two categories:

- G1 (blue) -includes fields related to social sciences, media studies, information science and management, computer science, health sciences, and other areas typically associated with theoretical, applied, or technical orientations.
- G2 (dark red) -includes fields directly connected to artistic and creative disciplines, such as art, digital arts, film studies, fine arts, design, and interactive art.

The relative size of each term reflects the frequency with which it was mentioned in the responses, with "art" and "digital arts" standing out as particularly prominent among G2, and "social sciences", "communication and media studies", and "information management" leading within G1.

This visual overview highlights the interdisciplinary character of the participant group. While many respondents come from media, management, or social science backgrounds (G1), there is also a strong presence of individuals with formal education in artistic and digital creative domains (G2). Such a composition is particularly relevant for projects dealing with digital cultural heritage, immersive technologies, and art-science-technology intersections.

Fig. 23. VR's main reasons for use.



Entertainment is by far the most common reason for using VR among respondents (VR users), with 46 users indicating that they use VR primarily for games (including desktop games), films, and other recreational activities. The second most frequently mentioned reason was *education and training*, selected by 39 respondents, suggesting that many participants also recognize the potential of VR beyond entertainment. *Creativity and art* were also important motivations, cited by 29 users, reflecting the use of VR as a tool for artistic expression and design.

Another frequently mentioned reason was *exploring new technologies*, chosen by 26 participants, which points to users' curiosity and interest in engaging with emerging digital tools. *Cooperation and teamwork* were less common, indicated by 6 respondents, while *research* purposes were mentioned only twice.

In the open-ended responses, some participants mentioned unique or niche motivations such as participating in research experiments, working on a project about deep space, using VR for development, or demonstrating VR applications to others. While each of these was mentioned only once, they illustrate the diverse ways individuals are engaging with the medium.

When describing their associations with VR, users highlighted a range of aspects, which are elaborated on in the following paragraphs. The associations related to the purpose or area of VR use clustered around three main themes:

- (1) entertainment perceiving VR as a toy, with links to gaming or gadgets, e.g.: *"I have used VR once, and it felt interesting and immersive. It reminded me of video games and gave a sense of being in a different world."* (EN_57, item 1);
- (2) an emphasis on the educational potential of VR (e.g.: EN_23, item 1);

- and (3) the use of VR in creative work, including the creation of experimental artworks as well as experiencing VR exhibitions, such as the popular immersive Van Gogh shows, e.g.: *"I am interested in creating and exploring VR as a creative medium and as a communications medium"* (EN_47, item 1) and *"Very nice in the framework of exhibitions (f.ex. statues of the Leuven Old City Hall; exhibition in Bozar, exhibition Antwerp Van Gogh; exhibition BAC ART LAB)."* (EN_34, item 1).

These categories were not mutually exclusive. Several participants mentioned multiple purposes side by side, combining, for example, artistic exploration with learning or gaming. For example, *"Design and implementation of VR environments in the context of artistic experimentation and educational purposes"* (EN_42, item 1) and "*Mostly for entertainment, but I did use a VR device once in an educational setting, and it was a really positive experience in terms of engaging the user"* (PL_32, item 1).

Social aspects were also mentioned among the associations with VR, although primarily in the context of spending time with people users already knew from outside the virtual world such as friends and family. Rather than emphasizing the creation of new relationships in VR, participants focused on the technology's potential to enhance shared experiences with existing social circles. For example, *"I associate it with meeting up with friends, spending time together, or having fun."* (PL_26, item 1) and *"I associate my experiences with my friends and family (playing multi-player games using vr)"* (EN_51, item 1).

Another prominent theme in participants' associations with VR was physical discomfort related to its use. In some cases, the only associations mentioned were intense symptoms of VR sickness. For example, *"With headaches and nausea..."* (PL_38, item 1) and *"getting a killer migraine"* (EN_14, item. 1).

While some participants were able to name other associations with VR, they still admitted that even when they recognized the technology's benefits severe discomfort significantly shaped their overall experience. For some, this resulted in actively avoiding VR altogether. For example:

"I associate my VR experiences with a powerful tool to amplify the potential of reality, especially in creative and educational contexts. It opens new ways of learning, designing, and experiencing content in a more immersive way. However, I also associate VR with a certain level of physical discomfort during use, which sometimes affects the overall experience." (EN_26, item 1) and *"It's a cool thing, but because of issues related to how poorly my inner ear tolerates the technology, I simply avoid it."* (PL_25, item).

Participants also shared associations related to the technological aspects of VR. These included references to technical issues, the high cost of equipment, and occasional mentions of augmented reality (AR). In addition, VR was frequently linked with novelty and the opportunity to experience something otherwise inaccessible. Respondents highlighted the interactive nature of VR, particularly its capacity to enable direct engagement with virtual environments and objects.

Participants also mentioned associations with virtual worlds, as well as with the realism and authenticity of the VR environment. Sensory aspects were highlighted as well, with several respondents emphasizing the importance of haptic sensations in shaping the immersive experience. For example, *"often underutilised or crappy graphics. Connection with the haptic is the most important for immersion."* (EN_8, item 1-2).

Beyond immersion, other frequently mentioned concepts included disorientation and presence,both reflecting users' awareness of the unique ways VR affects their perception of space, self, and reality. For example:

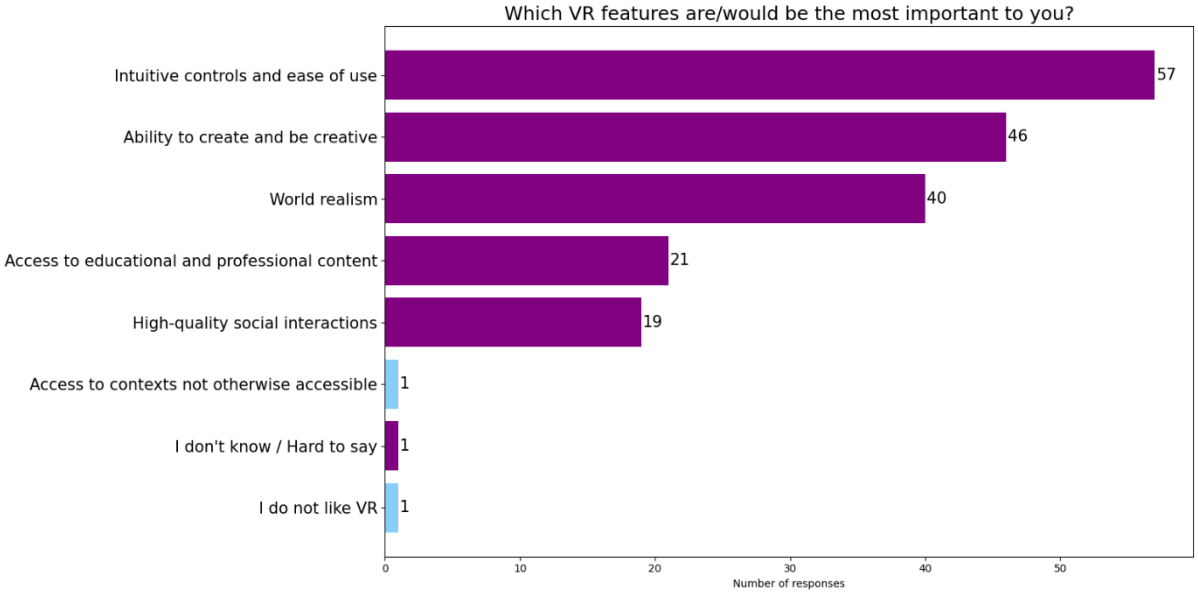
"My experiences in the VR environment so far can be associated with immersion, presence, and disorientation. The immersion reminds me of being absorbed in a film or video game completely transported. Presence relates to theatre or live performance, where despite knowing it's staged, your body and mind respond as if it's real. Disorientation is akin to vertigo or dream states, where spatial awareness and perception of time feel altered. Together, these evoke associations with gaming, cinematic storytelling, and even lucid dreaming." (EN_40, item 1).

Associations with VR also included emotional responses ranging from enthusiasm and curiosity to, in some cases, disappointment. While some participants expressed excitement about the possibilities VR offers (e.g.: *"An incredible way to gain new knowledge, experiences, and emotions. Some of the feelings I had while using VR goggles were unlike anything I've ever experienced in life."* (PL_33, item 1)), others noted that their actual experiences did not always live up to expectations (e.g.: *"In general I am content, but in most regards, there is room for improvement. The quality of image isn't at all what I'm used to in 2d, for example. The immersion that I felt I was promised only ever materialized half"* (EN_37, item 1)).

Finally, VR was also associated with challenge, both in a general sense, relating to the complexity of creating effective VR experiences, and in more specific comments. These included reflections on the importance of tailoring experiences to the intended audience, concerns about low visual quality, and doubts about the practical applicability of VR in certain projects. For example:

- *"Challenges with age groups, one VR solution is not always good for every age/target group, understanding this requires experience!"* (EN_35, item 1),
- *"I'm excited about the experience but scared by the difficulty of making it."* (EN_54, item 1),
- *"With something new, and interesting, but without established culture and daily interaction. I see it mostly as a cool technology gadget with potentials that are still not even developed"* (EN_58, item 1),
- *"Interesting experience. By itself it is not functional for the project. It is interesting to activate mixed design processes"* (EN_46, item 1).

Fig. 24. Question on which features are or would be most important to respondent users.



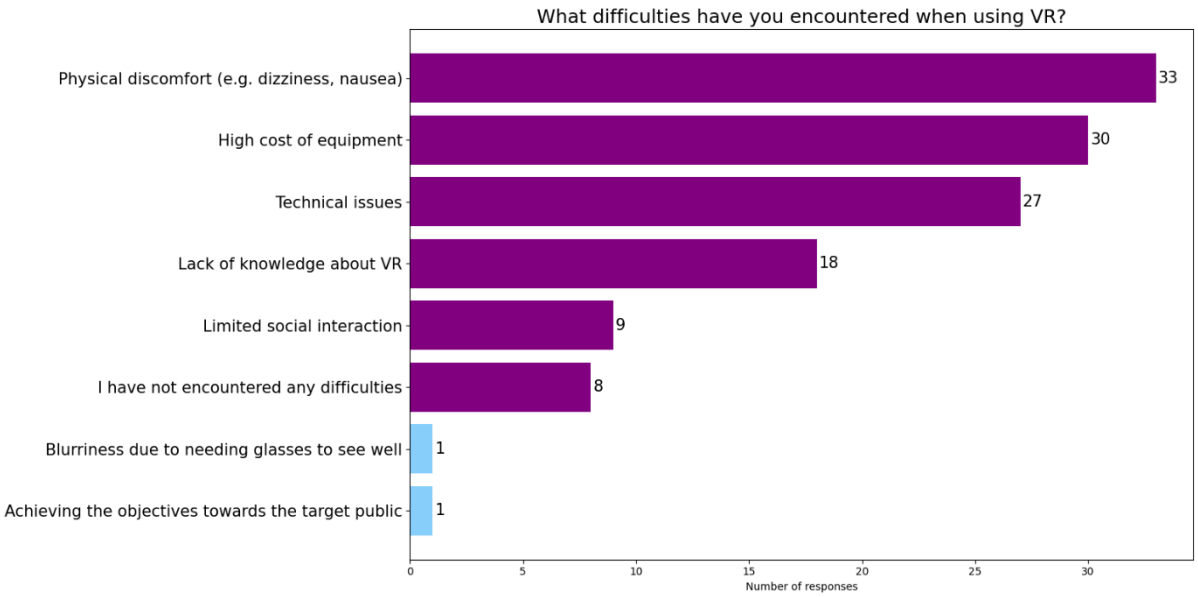
Based on the chart showing users' responses to the question about the most important features of VR, clear preferences emerge regarding usability and creative potential. The most frequently selected feature was "*intuitive controls and ease of use*", chosen by 57 respondents. This highlights that even among experienced users, accessibility and user-friendliness remain top priorities. The second most important feature was the "*ability to create and be creative*", indicated by 46 participants, underscoring the value of VR as a tool for artistic expression and design work.

"World realism" was the third most frequently selected feature, highlighted by 40 respondents. This suggests that users value virtual environments that resemble or convincingly simulate aspects of the real world, whether in terms of visual detail, spatial structure, or responsiveness. While this doesn't necessarily equate to immersion in a broader sense, it points to an appreciation for environments that feel coherent, consistent, and relatable within the VR context.

"Access to educational and professional content" was chosen by 21 users, confirming VR's relevance for learning and skill development. Slightly fewer participants (19) selected *"high-quality social interactions"*, which may point to lower expectations of VR's social functions or the current limitations of those features.

Other responses, such as *"Access to contexts not otherwise accessible"*, *"I don't know / Hard to say"*, and *"I do not like VR"*, appeared only once each and had no significant impact on the overall picture.

Fig. 25. Question about user difficulties with the use of VR.



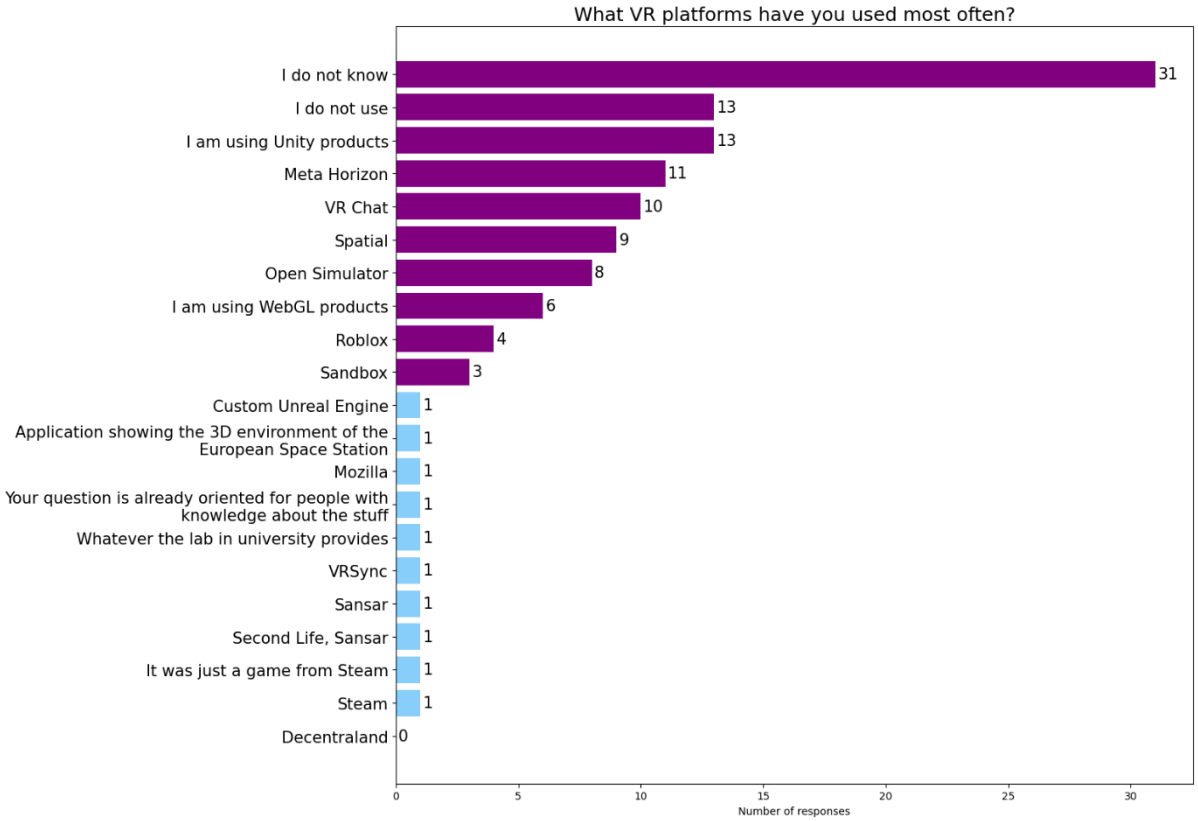
The most commonly reported difficulty among respondents (VR users) was *"physical discomfort"*, such as dizziness or nausea, mentioned by 33 users. In the context of VR users, this highlights the relevance of challenges related to VR sickness a factor that did not emerge during the Leuven testing phase. It is important to note, however, that during those tests, interaction with the platform was not conducted using VR headsets, which may explain the absence of such feedback at the time. This result reinforces the need to consider the physiological side effects of immersive VR experiences when designing content or platforms.

Close behind was the *"high cost of equipment"*, selected by 30 participants, indicating that financial accessibility remains a significant barrier to broader adoption of VR technology.

"Technical issues" were reported by 27 users, suggesting that hardware or software reliability continues to impact the user experience. Additionally, 18 respondents noted a *"lack of knowledge about VR"*, which may reflect limited access to training or onboarding, especially among less experienced users. *"Limited social interaction"* was mentioned by 9 participants, showing that some users find VR isolating or not sufficiently engaging on a social level.

Interestingly, 8 users stated that they have *not encountered any difficulties*, which may reflect either greater familiarity with VR or more positive experiences overall. A few unique responses were also noted, such as *"blurriness due to needing glasses"* and challenges in *achieving objectives for a specific audience* each of which was mentioned once, suggesting individual or context-specific concerns.

Fig. 26. The most commonly used VR platforms.

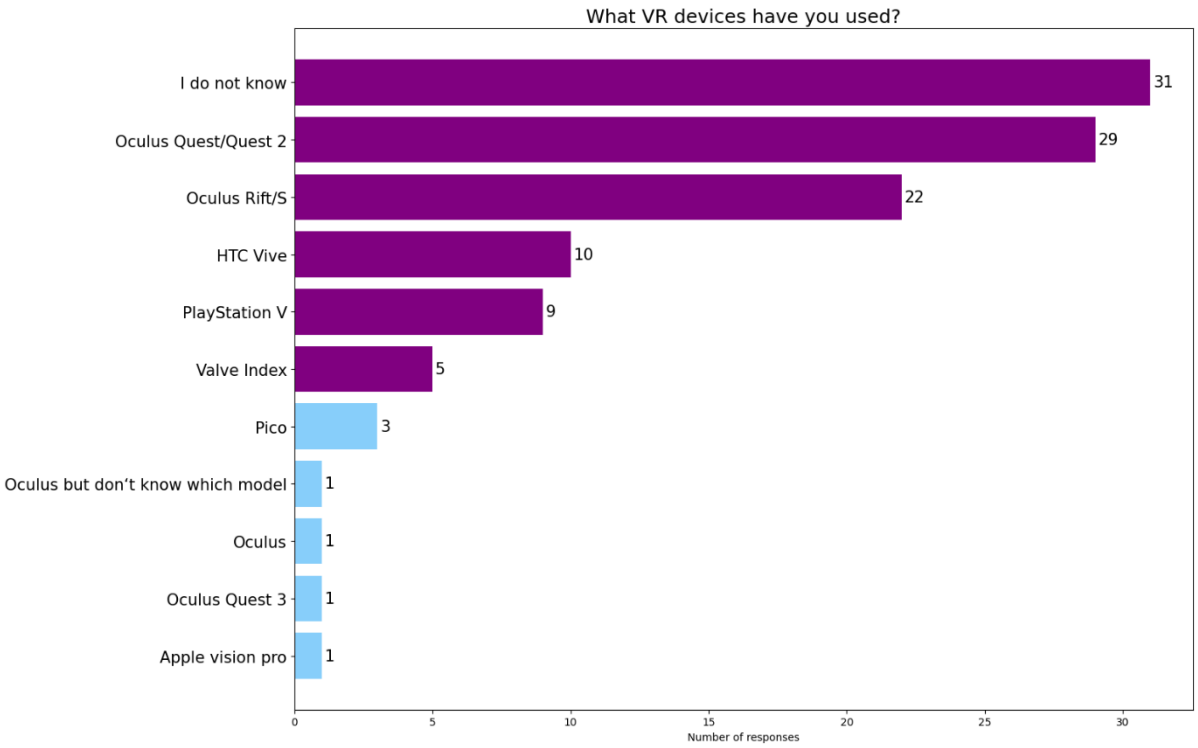


The most frequently selected answer to the question about VR platforms was *"I do not know"* (31 respondents), followed by *"I do not use"* and *"I am using Unity products"*, both with 13 responses. This suggests that many VR users especially those at an early stage of engagement, either interact with standalone content, development tools, or are unaware of the specific platform they are using. This aligns with the earlier observation that the majority of VR users in the sample self-identified as beginners, which may explain the limited awareness of platform names.

Among named platforms, *Meta Horizon* (11 responses), *VR Chat* (10), and *Spatial* (9) stood out as the most frequently used. These platforms emphasize social presence, creative collaboration, or immersive environments, indicating that even less experienced users are accessing virtual spaces designed for interaction. It's worth noting that Meta Horizon is the default environment for many Oculus devices, particularly the Quest line, which may also explain its relatively high usage.

Less common platforms such as *OpenSimulator* (8), *WebGL products* (*6*), *Roblox* (4), and others like *Mozilla*, *Unreal Engine*, and various educational tools were mentioned by only a few respondents each, revealing a fragmented landscape shaped by individual exposure, institutional tools, or developer interest.

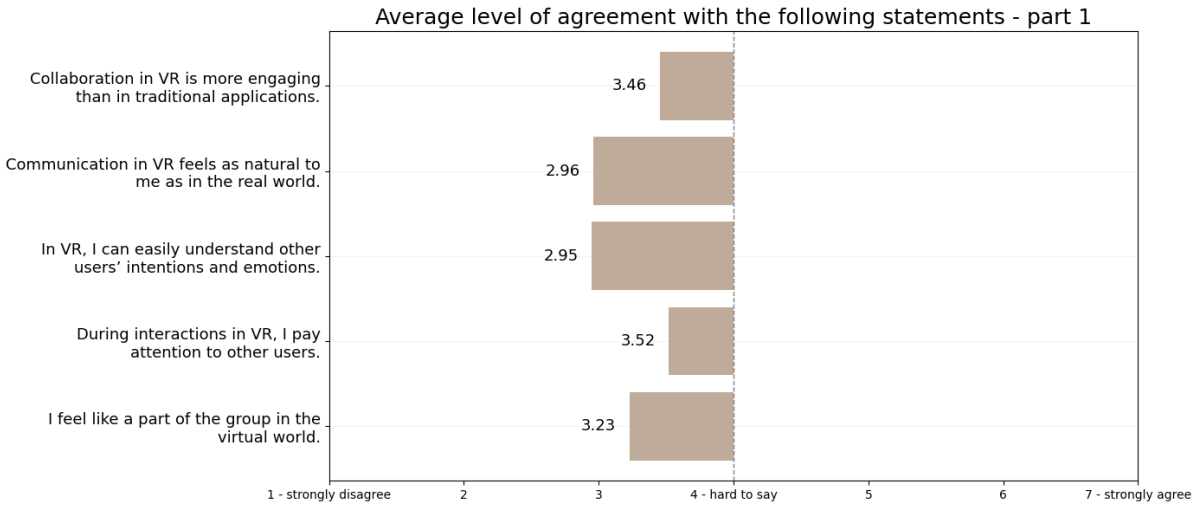
Fig. 27. VR devices mostly used.



A similar trend was observed in the responses about hardware: 31 respondents selected *"I do not know"*, again reflecting a general unfamiliarity with device specifications or use in non-personal, institutional contexts. However, among those who did indicate a specific device, *Oculus Quest / Quest 2* stood out with 29 mentions, followed by *Oculus Rift / S* (22), *HTC Vive* (10), and *PlayStation VR* (9). These results confirm that Oculus/Meta headsets dominate the user experience, and given their integration with Meta Horizon, it is likely that some users accessed this platform by default, possibly without realizing it.

Additional mentions included *Valve Index* (5), *Pico* (3), and a few individual responses referencing newer or less common devices such as *Oculus Quest 3*, *Apple Vision Pro*, or simply *"Oculus"* without further specification. This again points to a mix of personal and shared usage contexts, where device identification may not be clear or relevant for the user.

Fig. 28. Perceptions of social experience and interaction in VR environments.

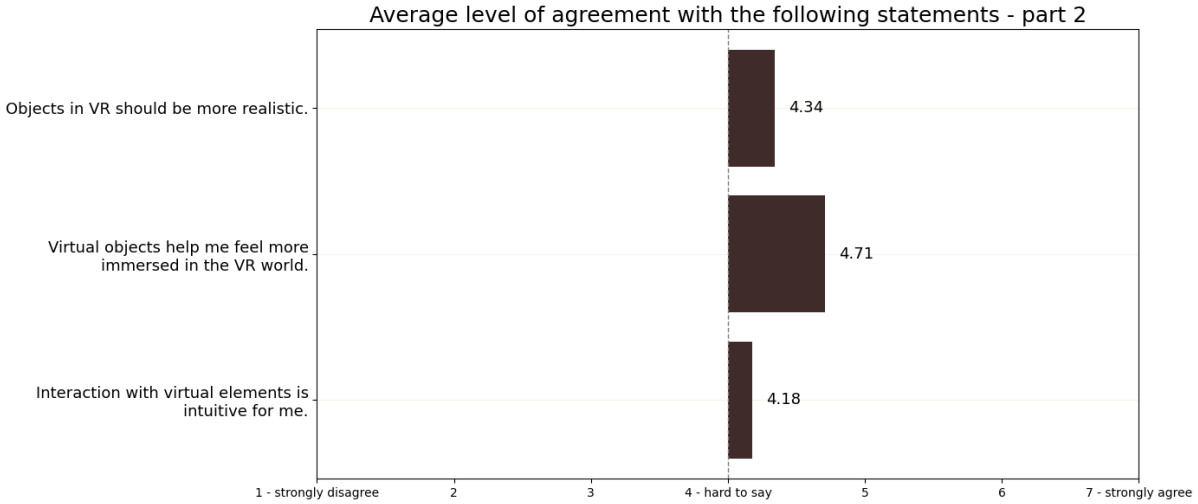


Responses from VR users regarding social experience and interaction show relatively low levels of agreement with statements related to communication, collaboration, and group dynamics in virtual environments. Ratings were given on a 7-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*, with 4 = *hard to say* as the neutral midpoint).

- The highest agreement was with the statement:
  "During interactions in VR, I pay attention to other users." (average 3.52), indicating moderate social attentiveness during virtual interactions.
- Other statements scored below the neutral point:
  - *"Collaboration in VR is more engaging than in traditional applications."* -3.46
  - *"I feel like a part of the group in the virtual world."* -3.23
  - *"Communication in VR feels as natural to me as in the real world."* -2.96
  - *"In VR, I can easily understand other users' intentions and emotions."* -2.95

These responses suggest that VR users do not yet experience virtual communication as natural or socially fulfilling. There is a notable gap between current virtual interaction capabilities and users' expectations for meaningful, emotionally resonant exchanges.

Fig. 29. Perceptions of object interaction and realism in VR environments.



Responses from VR users regarding interaction with objects and realism reflect generally higher levels of agreement. Here, users expressed more positive perceptions of how virtual environments support immersion and usability.

- The strongest agreement was with the statement: *"Virtual objects help me feel more immersed in the VR world."* (average 4.71), indicating that objects play an important role in enhancing the immersive experience.
- *"Objects in VR should be more realistic."* received a score of 4.34, pointing to a moderate desire for improved visual fidelity and authenticity.
- *"Interaction with virtual elements is intuitive for me."* was rated at 4.18, suggesting that many users find virtual interactions reasonably intuitive, though there is still room for improvement.

To sum up the average agreement of VR users with the sentences:

- VR users rate object-based and environmental aspects of the experience more positively than social and interpersonal dimensions.
- The data on social interaction reveals clear limitations in current VR platforms' ability to support natural conversation, emotional understanding, and group presence.
- Meanwhile, the emphasis on realism, intuitiveness, and immersion in responses about virtual elements confirms the importance of these features for user satisfaction, in line with earlier results on preferred VR functionalities.

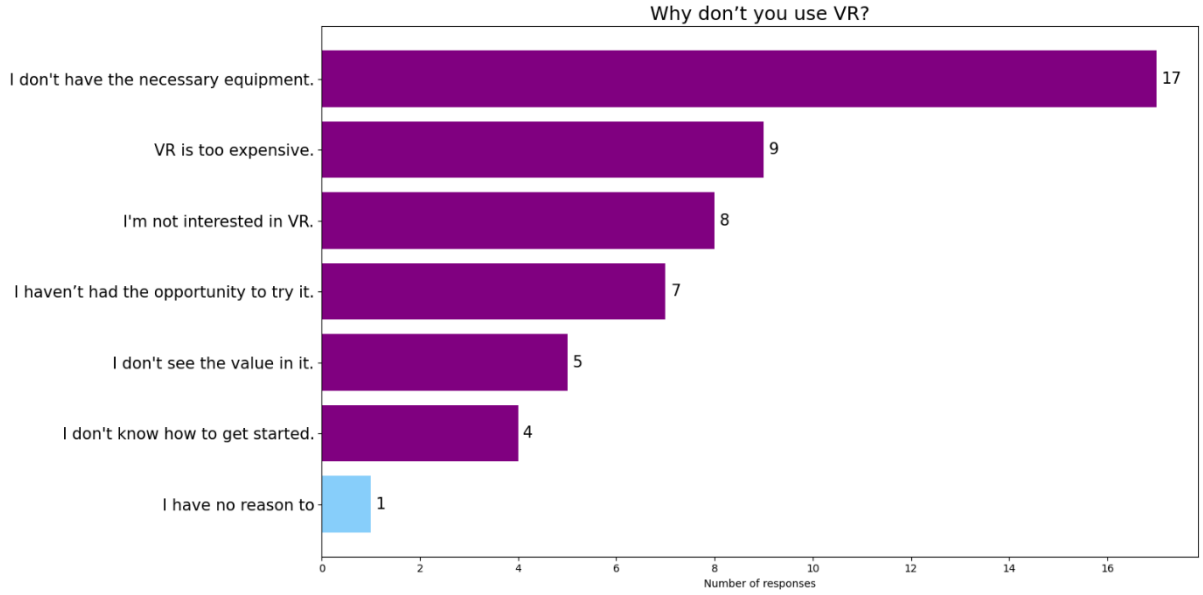
Moving on to the responses provided by non-users of VR.

The following charts summarize the answers given by participants who stated that they have not used VR, either due to lack of access, interest, or opportunity. These insights help to identify the key barriers preventing VR engagement, as well as the conditions under which non-users might consider trying it.

Among non-users, the most commonly cited reason for not using VR was *"I don't have the necessary equipment"*, mentioned by 17 respondents. This was followed by "VR is too expensive" (9 responses) and *"I'm not interested in VR"* (8 responses). These answers clearly indicate that cost and access remain the most significant obstacles for potential users, especially when combined with a lack of personal interest or perceived relevance.

Other reasons included *"I haven't had the opportunity to try it"* (7 responses) and *"I don't see the value in it"* (5 responses), which reflect limited exposure and unclear benefits. A smaller number of respondents admitted to *not knowing how to get started* (4) or simply *lacking a reason* to engage with VR (1). These findings suggest that both practical limitations and conceptual barriers (e.g., understanding, motivation) shape non-engagement with VR technology.

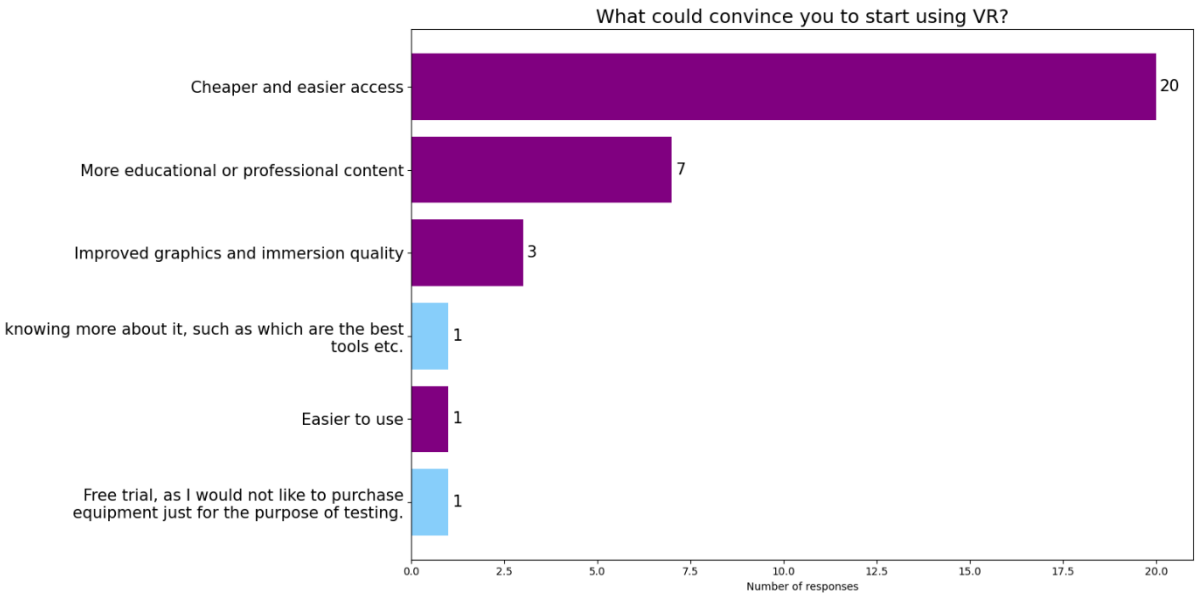
Fig. 30. Declared Reasons for not using Virtual Reality Technology.



When asked what might motivate them to use VR, non-users pointed most strongly to *"Cheaper and easier access"* (20 responses) as a key factor. This mirrors the previously identified barriers and reinforces the importance of affordability and availability in driving adoption.

Other motivating factors included *"More educational or professional content"* (7 responses) and *"Improved graphics and immersion quality"* (3 responses), indicating that while access is the primary issue, content quality and relevance also matter. Individual responses pointed to needs such as clearer information about tools, simplified usability, or a free trial to test VR without the upfront investment.

Fig. 31. Perceived drivers of willingness to try Virtual Reality.

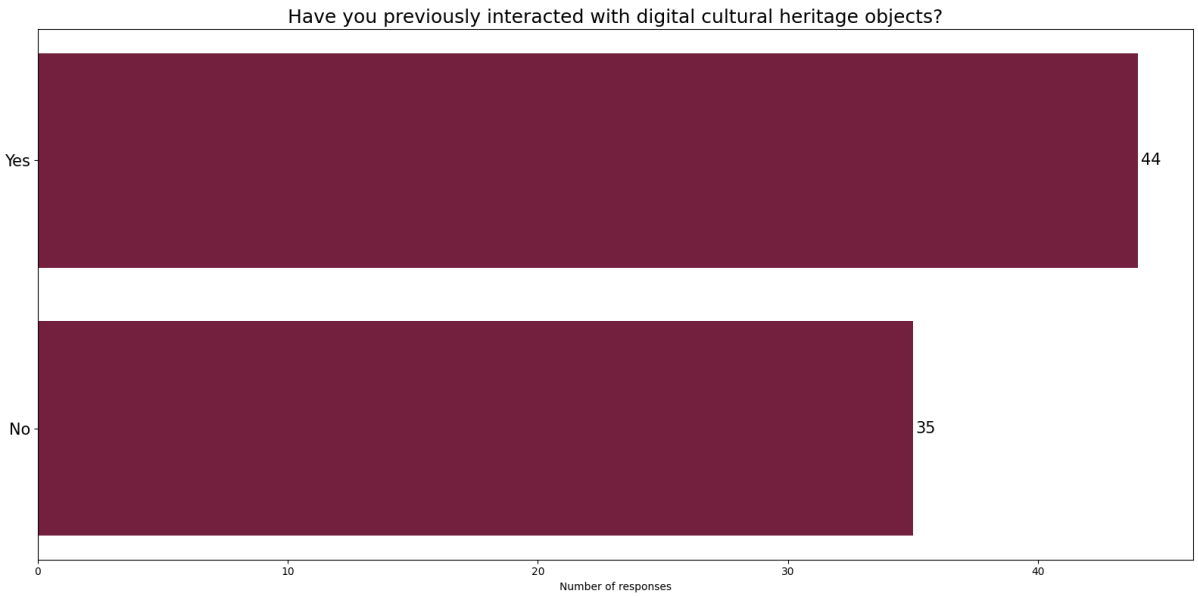


Taken together, the responses from non-users suggest that lowering the entry threshold both in terms of cost and complexity could significantly broaden interest in VR. Additionally, offering meaningful, professionally or educationally valuable content, and creating opportunities for first-hand experience, may help convert hesitant or curious individuals into active users. Addressing these barriers is essential for inclusive and sustainable expansion of VR technologies.

Within the IMPULSE project, we do not have control over the cost of VR headsets or hardware. However, what we can do is focus on developing valuable, meaningful experiences, and on raising awareness of the benefits of using VR particularly in the context of engaging with cultural heritage objects, whether through educational activities or artistic practice. By emphasizing content relevance and communicating potential uses, we can help make VR more approachable and attractive, especially for those encountering it for the first time.

Returning to the topic of cultural heritage, among respondents who identified as VR users, the question *"Have you previously interacted with digital cultural heritage objects?"* revealed a relatively balanced split, with a slight majority answering *"Yes"* (44 responses) and 35 respondents answering *"No"*.

Fig. 32. User Experience with digital representations of cultural heritage.



This indicates that a significant portion of VR users already have experience engaging with digital representations of cultural heritage, suggesting familiarity with digitized artifacts, museum content, or heritage-based virtual experiences. At the same time, the fact that over a third of users reported no prior interaction highlights the continued need for outreach, accessibility, and awareness-raising in this area-especially considering the potential of VR for education, interpretation, and creative practice within the cultural heritage domain.

When describing their experiences with digital cultural heritage, respondents referred to a wide range of examples including general digital objects and 3D models, as well as books, paintings, museum collections, and resources from Europeana. They also mentioned augmented reality experiences and cultural content encountered in video games. Places played an important role in these associations as well both in general references to historical sites and digital twins, and in specific mentions of scanned environments such as the Valletta underground and the Terezín ghetto.

Some participants also revealed their involvement in the active creation of digital cultural heritage. This included producing scans using LIDAR or photogrammetry, digitizing materials particularly books and paintings as well as providing consultation on digitization processes.

Some participants pointed to the opportunities offered by digital cultural heritage objects, particularly in terms of enabling new forms of user interaction with such materials. They also emphasized the value of making these resources accessible to people regardless of their geographic location or physical ability to visit museums an issue that became especially apparent during the pandemic.

In the context of the IMPULSE project, particular attention should be given to the challenges related to developing appropriate ways of engaging with digital cultural heritage objects. Participants pointed out issues such as low graphic quality, lack of detail, the absence of multisensory experiences especially touch and the isolation of objects from their original context, which can lead to them being perceived as artificial or unreal, e.g.: *"Artificial, floating in the air, unreal."* (PL_19, item 2).

The perceived artificiality of such objects can evoke highly negative reactions and a sense of being deceived, as expressed in the following comment:

"Distance, untrust, when virtual things trying to make me believe they are real, I just reject the all stuff cause I feel fooled" (EN_48, item 2).

Participants saw potential for addressing these challenges through the use of storytelling and by placing digital objects within a meaningful context an approach that was often linked to the importance of site-specific references. For example:

- *"2D and 3D digitization of heritage objects, the more it acts as a digital twin, the better. When these results can be used in VR applications, that is good. It gives context to otherwise isolated objects. An example from my own work is an isolated fragmented Assyrian palace relief, contextualized in a 3D model of a reconstructed palace room."* (EN_35, item 2).

These survey results reinforce the high-level goals of accessibility and inclusivity, and point to concrete low-level priorities such as streamlined onboarding, UI clarity, and interoperability with CH standards that inform the Experiencing and Authoring domains in §9.

8.3 Interviews

The interviews conducted as part of the IMPULSE project serve as a crucial source of qualitative insights into the user experience with immersive VR environments. These interviews were undertaken with a range of participants from various professional and academic backgrounds, providing valuable data on user expectations, challenges, and perceptions of immersive VR technologies. By analysing their reflections on the platform, the interviews offer a deeper understanding of how users engage with immersive systems, the functionalities they prioritize, and the barriers they encounter while using the technology.

Between March 25 and April 11, 2025, researchers from the IMPULSE project conducted and prepared nine interviews for further analysis, including transcription, description, and initial coding. Four interviews were conducted remotely, while five took place in person. Most of the interviews in this first phase of the study were conducted

with representatives of Group 1. Three interviews were held with representatives of Group 2, and one interview involved a representative from Group 3.

The findings from these interviews complement the quantitative data gathered from surveys and other structured activities in the project. They provide nuanced, in-depth insights into personal experiences that contribute to the iterative design process of the IMPULSE VR prototype. These interviews serve as an important source for understanding how users conceptualize and navigate the virtual environment, as well as their emotional responses and reflections on the platform's potential.

Given the composition of participants, the current dataset and findings are primarily oriented toward the educational dimension of VR use. This focus aligns with the themes explored during the workshops held in Leuven, where the potential of VR in pedagogical contexts was a central topic of discussion. The involvement of G1 participants in this phase reflects their strong connection to the educational applications of the technology. As future research continues, greater emphasis will be placed on exploring the experiences, needs, and expectations of participants from G2 and G3. This will ensure that the platform is refined to meet the needs of a diverse range of user groups and will support future iterations of the IMPULSE VR platform that cater to both creative and curatorial use cases.

The insights gathered from these interviews will be synthesized to inform the iterative development of the IMPULSE VR prototype, guiding the refinement of its functionalities and the design of an inclusive, user-centred immersive environment. These interviews, therefore, represent a critical foundation for understanding user engagement, emotional responses, and perceptions of immersive technologies, shaping the strategic direction for the platform's future iterations.

In the case of participants from G2 and G3, recruiting additional interviewees will benefit from collaboration with WP5 and the growing IMCo (IMPULSE Community of Practice) network. This process will naturally require time, as well as adjustments in scheduling and interview formats to accommodate participants from these groups, who tend to be less readily available than those in G1. Postponing the in-depth interviews with G2 and G3 representatives may also prove advantageous, as conducting these conversations after gaining access to a stable version of the platform prototype is likely to yield more concrete feedback and actionable recommendations.

The interviews were conducted by: MA, GG, AH, PK, ST, KT and ZV. The transcription files include the initials of the researcher who conducted each interview.

The following sections present the results of a preliminary thematic analysis conducted using MAXQDA. The aim of this analysis was to identify key barriers to VR use, users' expectations regarding VR, and functional features perceived as useful or desirable. These initial findings offer a foundation for further, more detailed analyses, which will be carried out in the next phases of the research.

Interview findings demonstrate how motivational and affective benefits map onto IMPULSE's high-level experience goals, particularly memorability and learning (WHY 2), creative reinterpretation (WHY 4), and sustainability and re-use (WHY 7). They also reveal operational low-level goals -such as tutorials, role-based collaboration, and object manipulation -that are required to implement these intentions.

Interview findings map motivational and affective benefits onto the seven high-level goals (§5.6) and surface operational low-level requirements tutorials, role-based collaboration, and object-inspection toolsthat are specified in §9.

At this stage of the IMPULSE project, in line with the planned timeline, it is particularly important to deliver practical insights for WP2, especially in relation to the design of the platform. The current analysis is therefore intended to inform ongoing design decisions and support the development of user-centred solutions.

8.3.1 Indicated barriers

Participants' statements revealed a wide range of barriers related to the following aspects:

1. **Physiological barriers**, including symptoms of VR sickness and headaches, discomfort during prolonged use, difficulty using VR headsets while wearing glasses, discomfort caused by the perceived weight of the headset, and concerns about hygiene when using shared equipment, e.g.:
    a. *"There are medical reasons why a lot of people won't have had regular people in our laboratory refuse to try experiences because they anticipate having motion sickness or getting migraines."* (AH01_transcription, item 141-142)
    b. *"For example, there are those who perceive nausea, or those who see blurred inside the viewer (which often depends only on an eye distance setting that is not the same for everyone)."* (GG01_transcription, item 64)
    c. *"However, there are obstacles related to the fact that objects like headsets are not comfortable to use. They are very bulky"* (MA01_transcription, item 43)
    d. *"Well, during corona, you suddenly felt a bit uneasy about whether you might pick up some bacteria. Since then, I've had an awareness of the exchange of physical proximity via the glasses."* (ST01_transctription-eng, item 48)
    e. *"To be honest, the main reason is quite mundane, I have problems with my eyesight. Without glasses I can only see monocularly, and when I put them on, they simply don't fit under the VR goggles. This is quite a discomfort for me and puts me off a bit."* (KT01_transcription, item 27)
    f. *"After 10/15 minutes many people need to "get out". This represents a constraint."* (MA01_transcription, item 47)
2. **Affective and cognitive barriers**, including fear among novice users caused by visual isolation from the physical environment and feelings of disorientation; uncertainty about what to expect during VR experiences; boredom with available VR content; a perceived lack of social readiness to embrace VR; viewing VR

as an impractical, game-related gadget with limited everyday use; lack of accessibility and inclusiveness for people with special needs; the belief that VR contributes to information overload and sensory overstimulation; perceiving VR as a prosthetic version of reality; the feeling of being confined or enclosed in a space that is imposed rather than chosen; the belief that VR content production is prohibitively expensive; and viewing VR through the lens of past, not particularly positive, experiences with the technology, e.g.:

a. *"Fear sometimes comes after, especially when you're talking about a VR headset, and they suddenly can't see their surroundings. Some people do feel disoriented."* (AH01_transcription, item 70);
b. *"Even when I've had people who have had no experience, they're not sure what to expect. And then once they're inside an experience. Okay, there's surprise, enthusiasm, fear sometimes. but they're they never seem to have expectations per se. They're, they're always quite unsure of what to expect."* (AH01_transcription, item 63-64);
c. *"Equipment limitations, financial limitations and the lack of admiration for those VR activities or VR exhibitions I've had to deal with, which, as I say, are on the one hand spectacular, on the other monstrously boring and falsify reality, although this pleases the general public. It has to be realised at a very high, truly extraordinary level to impress specialists. I saw three VR exhibitions in Japan in December and got tired."* (PK01_transcription, item 48);
d. *"Well, the question is how to look at social reality, whether this social reality adapts to some technological change, whether it sort of, that is, after the fact, something happens, or whether it anticipates these technological changes and already adapts and then when these technological changes come, society is ready for it."* (KT02_transcription, item 78);
e. *"One might expect would not adopt this technology, so until this becomes something that is perceived as being useful for more than just games."* (AH01_transcription, item 143-144);
f. *"Yes, it is a technology reserved for a healthy population. For a healthy society. All the people who are a bit off, well, non-normative, they often feel uncomfortable in such spaces, not to mention some medical conditions. This is a technology that we should have a choice to use, whether we use it or not. It is spectacular, but in my opinion, it also brings with it a whole range of different pitfalls."* (PK01_transcription, item 50);
g. *"Well, in virtual reality, well, let's say, if we extend it to reality, let's say, to this augmented reality, well, then we are obviously dealing with an extra portion of information which pops up for us somewhere all the time. And I think that if meditation leads us somewhere to some kind of inner peace and tranquillity, well, the opposite is just such an excess of information. And this overload of information will also lead to the opposite, to some, I don't know, mental disorders or simply weaker mental health."* (KT02_transcription, item 64);

h. *"The other reason is psychological: the fact of having, for example, wrap-around glasses that provide not only visual but also auditory immersion makes some people feel uncomfortable."* (MA01_transcription, item 41);
i. *"VR is the creation of a space to which humans are constrained."* (PK01_transcription, item 78);
j. *"But still, nothing can replace the touch, the smell of live wood, let's assume. Artificial worlds of all kinds will only be a prosthesis of reality and will work as prostheses work: they are getting better and better, but they are only prostheses."* (PK01_transcription, item 34);
k. *"Often, it is a matter of production costs, which one imagines to be very high, but in reality, it is not so, or in any case costs are very similar to the creation of an animated video"* (GG01_transcription, item 61);
l. *"Maybe there are people who are wary because they tried technologies from 10 years ago, not so sensational, and they believe VR is just that. Often, the viral technologies of the beginnings spoil the field for subsequent developments."* (GG01_transcription, item 61).

3. **Equipment-related limitations**, including the high cost of VR hardware; lack of access to appropriate equipment and supporting infrastructure; the belief that powerful computers are necessary to use VR; difficulties related to the creation and maintenance of multi-user virtual environments (MUVE); the dependency of VR experiences on stable power supply; and the need to constantly keep up with rapid technological changes and updates, e.g:
    a. *"Accessibility is still an issue. It's still something again expensive, relatively expensive to buy"* (AH01_transcription, item 163);
    b. *"When it comes to working with students, I think the main problem is the lack of availability of equipment. At the university, we don't have VR goggles or any infrastructure that would allow us to use this technology in class."* (KT01_transcription, item 29);
    c. *"To be able to run it, you also need a fairly beefy computer"* (ZV02_transcription, item 32);
    d. *"The technology gallops away"* (ST01_transctription-eng, item 45)
    e. *"In company presentations and communications, for example, there is often a reference to the dimension of multi-user interaction, but in practice, it is technically complicated to set up in an experimental environment."* (MA01_transcription, item 43);
    f. *"And all these activities hinder our perception for trivially simple reasons. For example, because of the lack of electricity."* (PK01_transcription, item 40-42).
4. **Barriers related to the competencies required to use VR**, including a lack of relevant competencies; absence of adequate support during implementation; limited time to explore or integrate VR into one's practice; and the belief that using VR requires specific technical skills and formal training for users, e.g:
    a. *"There is a lack of literacy and this creates resistance."* (GG01_transcription, item 61);

b. *"With VR and AI you always need someone to facilitate the devices"* (ST01_transctription-eng, item 55);
c. *"The time constraints involved in educating future artists. The pace of working with them, the number of students and the activities involved, such a daily grey day of a teacher, from my perspective, completely excludes such activities. It can be done on the basis of workshops, some one-off meetings, but not continuous full learning, only as a gadget and a kind of break from the hard reality related to the specifics of our work."* (PK01_transcription, item 46);
d. *"Also, my technical knowledge is lacking, I'm not an expert on how to use such devices, so I would need some training or support to start using it at all."* (KT01_transcription, item 27).

5. **Barriers related to the quality of VR content**, including the perception that available content is uninteresting or not suited to a broad audience often due to its origins in STEM fields; the lack of high-quality, engaging content; and concerns that VR may prioritize technological spectacle over meaningful substance; some participants also expressed fears that VR could pose a threat to traditional forms of learning and cultural experience, e.g.:
   a. *"I also feel there's a bit of a stigma associated with it, specifically in the gaming sphere, is that I do not like to associate. It doesn't have the same cultural capital that, let's say, a single-player 3D video game like The Witcher has, that I can justify in terms of my research. VR I find more difficult to justify beyond the whole field of ludic studies, like game studies, like ludography, whatever you want to call it."* (ZV02_transcription, item 32);
   b. *"Yes, I have happened to hear criticisms, mainly from people who are more 'traditional' in their approach to communication and teaching. From their perspective, VR can be seen as too 'flashy' and distracting from the educational content. Such proverbial form over substance."* (KT01_transcription, item 31).
6. **Limited immersion compared to that experienced in the physical world**, including the reduction of immersion caused by disconnection from the physical environment; the absence of real sensory input, particularly touch; issues with equipment fit such as VR headsets not sealing properly and allowing light to enter around the nose bridge, which disrupts the sense of full isolation; and the limitation of interpersonal contact, which some participants viewed as essential to meaningful engagement, e.g.:
   a. *"These notions of immersion, that it actually would achieve the opposite of what I'm talking about now, that instead of it heightening immersion when people go and see a theatre performance and are more aware of their perception, that actually it will alienate them more from like the materiality in which they find themselves."* (ZV02_transcription, item 42);
   b. *"Sometimes it's a bit crappy, in the sense that, for instance, the goggles are too big, and then you see (...). Like you see, you don't, you're not completely immersed in the environment. Because the light is coming from the room, and, or you hear other people chatting. So, yeah, you should be immersed*

in the environment, but, like, it's literally impossible if you're not in a place that allows you to be immersed and focused." (ZV01_transcription, item 46);

c. *"This is because there is another limitation, which can occur, for example, when there are VR installations, related to the fact that the user who is testing is alone, and there is little interaction with those who are watching or assisting with the test"* (MA01_transcription, item 43).

7. **Lack of perceived need to use VR**, e.g.: *"I can't say that I am actively and systematically exploring this topic, as no such specific need has arisen so far"* (KT01_transcription, item 11).
8. **A belief in the limited applicability of VR**, e.g.: *"cost and limited application at the moment the primary use"* (AH01_transcription, item 139).
9. **The impact of the "wow effect" among beginner users**, e.g.: *"On all occasions when I have used headsets for experiments or training sessions, it emerged that for most users, it was their first time trying this type of equipment. This situation, in my opinion, generates a level of distortion in the results because users are very impressed"* (MA01_transcription, item 41).
10. **Ethical concerns:** *"But for AI, there's also the ethical consideration, I think, about using all that energy in all those data centres, which, again, I presume by now there's also data centres in the EU that are being used, but still is primarily located in North America. And so I do think there is a significant -I'm thinking of the correct term right now. I think there is a very significant threshold of accessibility, where when you have access to those technologies, then, yes, they can definitely augment your workflow. And I myself am fairly positive when it comes to using computers, digital media in general. However, I do feel that specifically -like I feel more positive about VR and AR than I do about AI"* (ZV02_transcription, item 34).
11. **Reflections on the influence of transhumanism on the development of VR**: *"Well, it depends. If, thinking from the side, if we went in the direction of transhumanism, that is, that people would be augmented by artificial intelligence through certain connections between the biological layer and the technological layer, well, of course, these could be new scientists. At the same time, they wouldn't exactly be people as we understand them and today."* (KT02_transcription, item 83).

Some of these barriers reflect perceptions or assumptions that may not necessarily align with technological realities once accurate information about VR is obtained. Nonetheless, they currently function as real obstacles for users and significantly shape their willingness or reluctance to engage with the technology.

The interviews yielded a rich set of functionalities that participants encountered during their own experiences with VR. These functionalities vary in terms of complexity and ease of implementation. Rather than representing a list of mandatory requirements for the prototype being developed within the IMPULSE project, they serve as indications of what users believe could or should be included in a VR environment. As such, they offer valuable recommendations for the future activities of cultural institutions.

Among the functionalities mentioned were:

- **the ability to interact with objects**, including viewing 3D objects, changing the size of objects, copying and moving them within the environment, touching or simulating tactile interaction, approaching objects to observe them more closely, and importing custom 3D objects, e.g.:
  - *"And one of the fascinating points was how everyone could grab the sculpted piece and create a duplicate and scale it and interact with it. So everyone basically had a copy of the sculpture in their own hands and virtual hands and was able to interact with it in ways that would not be possible, or in the real world, or would be expensive or would be damaging, which again, it depends on what your goal as an artist is some people. Some artists want their art piece to be lived right? Maybe the destruction of the art piece is its very purpose of existing. So, having an art piece that's easily replicated would defeat the point. But it depends what the artist's objective is for somebody else."* (AH01_transcription, item 190-191);
  - *"But, for me, VR is like a bit more, like, it involves, it should involve more, like, sensory experiences, and really being able to move, maybe, or to pick things, or, I don't know, to sort of, yeah, interact with the objects."* (ZV01_transcription, item 32);
  - *"being able to zoom in and get a lot closer than you would if you are seeing the thing in person."* (AH01_transcription, item 232);
- **navigation-related functionalities**, including intuitive and familiar input methods similar to using a computer mouse or keyboard, as well as comfortable and immersive hand tracking solutions that eliminate the need for physical controllers, e.g.:
  - *"On the other hand, the impact of novelty is more contained when, for example, a video game (with mouse/keyboard input) is used as a platform for experiments. These are still virtual worlds or realities, but these platforms have largely codified and familiar interaction modes for a good portion of users. Of course, there are differences in age, experience, etc., but generally, what I find is that with systems using traditional mouse/keyboard input, there is a lower barrier to entry compared to using headsets."* (MA01_transcription, item 41);
  - *"it's definitely improving the fact that hand tracking is becoming so seamless and the need, the known, the lack of need for controllers that is obviously going to make experiences a lot more seamless because people can interact with the virtual scenes in a more intuitive fashion. It's not about learning which button to press, or which joystick to push. So I think it's going to become a lot a lot easier."* (AH01_transcription, item 164-165);
- **functionalities related to movement within the virtual world**, including the ability to rotate the user's point of view and to move between locations using portals, e.g.:

- *"They can simply turn round and see the rest of the room"* (ST01_transctription-eng, item 36);
- *"The concept of portals that you can walk through. So you can immediately walk from one environment to a completely different environment which doesn't even necessarily match in scale."* (AH01_transcription, item 205-207)

– **functionalities related to camera and perspective**, including the ability to change and select different points of view, as well as to adjust camera settings, e.g:
- *"In terms of scale, like the ability for a VR experience to have you walk around as if you were a child. So, seeing everything from a lower level, or the way things, the way your expectations of the world can have something appear real or in proportion, or suddenly be a miniature item, even though it's the same object your own wired up perception, preconceived notions."* (AH01_transcription, item 198-199);
- *"by being able to choose your own point of view"* (AH01_transcription, item 236);
- *"make a camera movement through a linear drawing, or theoretically move around in the space"* (ST01_transctription-eng, item 26);

– **multi-user functionality in real time**, allowing multiple users to interact within the same virtual environment simultaneously, e.g.:
- *"virtual spaces and 3D assets can become not only spaces for acquiring knowledge but also spaces for design, for example, by prototyping solutions, concepts, and projects in real-time among different connected users."* (MA01_transcription, item 51);

– **functionalities related to the specific nature of virtual environments**, including the use of spatial sound to enhance immersion and support spatial orientation; the ability to break free from physical laws such as gravity; and the possibility to manipulate space and time within the environment, e.g.:
- *"spatial sounds, which also draws attention to where the sound comes from"* (ST01_transctription-eng, item 43);
- *"In VR, you don't need to stick to the rules of reality, so sometimes it helps to try and find something that lends itself more naturally to the medium rather than replicate what we're familiar with from reality."* (AH01_transcription, item 86-89);
- *"its ability to manipulate space or manipulate time to surprise and engage the audience in an unexpected way, giving them a novel experience."* (AH01_transcription, item 85-86);

– **the ability to create virtual galleries**, for example, to exhibit student work or other curated collections, e.g.:
- *"import three-dimensional materials created by students to make virtual galleries, which if you want also looks a lot at the dimension of the metaverse, therefore of shared spaces."* (GG01_transcription, item 55);

– **the ability to draw in 3D within the VR headset**, enabling users to create spatial sketches and visual annotations directly in the virtual environment, e.g.:

- *"a piece of software -I can't think of the name right now -where you can draw in three-dimensional space, under the VR glasses, you have the VR glasses on and draw with them."* (ST01_transctription-eng, item 25);

- **functionalities related to the creation and experience of films**, including support for 360-degree video content and the use of visual effects (VFX) within the VR environment, e.g:
  - *"Blending of different locations and different storylines in 360-degree space"* (ST01_transctription-eng, item 35);
  - *"You're freer to choose your camera angle and you can use a studio set by working cinematically and you can work with VFX who can add a ceiling or you can use a complete 360-degree world."* (ST01_transctription-eng, item 58).

In addition to the desired functionalities, interview participants also shared a wide range of expectations related to the use of VR. These included:

1. **Increased accessibility** -enabling broader access to places, experiences, and experts that might otherwise be out of reach, e.g.:
   a. *"being able to visit, to see, to interact with a lot of experiences that otherwise might not be available to you. To be able to do those virtually is a huge bonus from an education perspective."* (AH01_transcription, item 218);
   b. *"A virtual classroom can, for example, facilitate the presence of experts who might not otherwise be physically present. A video call could also do it, but the experience is completely different. In a collective immersive space, you are aware that you are sharing that virtual place, and you can perceive the presence of other people (because it simulates reality). It is something that could change the course of certain paths and, above all, it could lead students to have a better predisposition towards group work (gain experience during the training years of what the world of work will be like)"* (GG01_transcription, item 78);
   c. *"VR could improve the learning of subjects such as science and history (e.g. virtual tours in ancient Rome), to give pupils a more tactile experience, compared to a classic visit to the museum."* (GG01_transcription, item 53).
2. **Support for specific activities**, such as skill development in simulated environments; historical event reconstructions; documentation of crime scenes; simulation-based analysis of complex phenomena; collaborative prototyping; 3D modelling; running simulations; artistic creation; preserving experiences; supporting traditional teaching activities; and enriching content with annotations, e.g.:
   a. *"Again, safety and training or use of equipment which you would not have access to. So again, we've seen the examples with medical training. But obviously we could have simpler things. I don't know VR experiences where kids learn how to cook, you know, which is safe, because you don't have any real fire, but they could still be learning how to, you know, prepare and handle knives and things of the sort in a manner that doesn't put them*

at risk. So there's a lot of, I think, a lot of applications in in every possible field for learning using. VR." (AH01_transcription, Poz. 221-224);

   b. *"Regarding my field, communication, VR opens up fascinating possibilities. For example, one could analyse how people behave in different simulated social situations, how interactions change depending on context, space, distance."* (KT01_transcription, item 22);
   c. *"Virtual spaces and 3D assets can become not only spaces for acquiring knowledge but also spaces for design, for example, by prototyping solutions, concepts, and projects in real-time among different connected users."* (MA01_transcription, item 51).

3. **Further development of VR technology**, especially in relation to more comfortable hardware solutions and advances in spatial sound, e.g:
   a. *"Another example is that of devices that become lighter and integrated into people's daily clothing, ensuring a more massive adoption."* (GG01_transcription, item 74);
   b. *"But I also like spatial sound, for example. So, VR could develop even more in that area. Yes, there would be more."* (ST01_transctription-eng, item 58).
4. **The ability to convey content in a new and original way**, offering novel forms of engagement and expression, e.g:
   a. *"As far as school teaching is concerned, on the other hand, VR could improve the learning of subjects such as science and history (e.g. virtual tours in ancient Rome), to give pupils a more tactile experience, compared to a classic visit to the museum. Gamification has ramifications everywhere and could be a method to reinforce teaching."* (GG01_transcription, item 53);
   b. *"In the educational field, it would be very interesting to work with VR tools to create scenarios and environments where users can move around and have design experiences."* (MA01_transcription, item 51);
   c. *"I would use it like as a sort of engagement tool."* (ZV01_transcription, item 84).
5. **The expectation of voluntary use**, emphasizing that VR should remain an optional tool, not a compulsory requirement: *"It is a technology that we should have a choice to use, whether we use it or not."* (PK01_transcription, item 50).
6. **High-quality graphics**, with users expecting visually appealing and detailed environments: *"If you've got a high, you know, like a high detailed scan, 3D scan of a of an oil painting or something of the sort experiencing it and actually seeing the different levels of the paint build up."* (AH01_transcription, item 230-231).

One aspect that, while obvious from a UX perspective, remains important to emphasize is the need to tailor content to the intended audience. For example:

"Try to be more attractive, give exclusive content. This has already been proven and has not attained the desired effect, because those who join are already skilled experts. Yet, you have to work on being attractive. For example, this is a separate market from that of those who go to the cinema. The latter does not necessarily translate into the market of people

who use VR apps. Therefore, it is necessary to diversify and intercept that target." (GG01_transcription, item 74).

Expectations were also expressed in relation to the inherent characteristics of VR. For example, one participant emphasized the importance of designing VR experiences with the physical space in mind the actual space in which users will interact with the environment:

"I wouldn't separate the two. The virtual, the physical, the studio space is still an integral element of a lot of virtual reality experiences, if nothing else, from a safety perspective, making sure that that people do have space to navigate, that the experience you're creating isn't encouraging the user to move in a way that might cause them or people around them, or objects around them, any harm or damage, so the space itself cannot be separated from the use. Then there's also on the experience itself. Some experiences might be designed for minimal movement." (AH01_transcription, item 97-98).

This participant also highlighted the awareness that VR will not replace the physical world; however, it was acknowledged that it offers more possibilities than traditional means of visualizing content:

"The moment you're going to be missing out on smells, on sounds and things of the sort, but it's still better than nothing for people that might not have a way of experiencing these things. And VR is a step up from just visualizing just seeing pictures on a website or a Youtube video, because you can actually have some agency and walk around in these sites and things of the sort." (AH01_transcription, item 220-221).

Finally, a suggestion was made regarding what could increase interest in VR among non-users namely, the opportunity to try out VR equipment for free:

"Definitely the possibility of renting equipment or even creating a VR studio at the university that we could use during classes. This would be a huge improvement, as currently access to such equipment is very limited." (KT01_transcription, item 38).

8.4 Synthesis and Cross-case Analysis

8.4.1 Synthesis and Cross-case Analysis

The synthesis of results across the three research methods participatory workshops, quantitative surveys, and semi-structured interviews has provided a nuanced understanding of the diverse ways users from various professional backgrounds interact with the IMPULSE VR prototype. These methods were employed to triangulate data and uncover deeper insights into users' expectations, challenges, and functional needs. This synthesis not only identifies common barriers faced by users but also offers key

recommendations for refining the prototype to better suit the needs of specific user groups.

8.4.1.1 Comparison of Results from Three Methods

The three research methods employed in this study participatory workshops, surveys, and interviews complement each other, yielding a holistic view of user engagement with the VR system.

1. **Participatory Workshops:** These workshops provided real-time interaction with the prototype, fostering immediate feedback and collaborative scenario development. The interactive nature of the workshops allowed participants to engage deeply with the system, generating spontaneous insights into usability issues and emotional engagement. The workshops also revealed immediate technical problems such as system instability, slow performance, and difficulties in navigating and manipulating content. These observations, made during active interaction with the system, highlighted the users' reactions to the prototype in practical conditions, with a particular emphasis on the technical difficulties they encountered.
2. **Quantitative Surveys:** The surveys were designed to provide a broader and more structured view of users' perceptions of the system. Through a standardized set of questions, the surveys captured data related to usability, immersiveness, narrative engagement, and interaction patterns. They provided statistical evidence of the trends observed in the workshops, notably confirming concerns about system instability, slow content loading, and difficulty with spatial movement. In addition, the surveys highlighted specific user expectations around accessibility and personalization features, such as avatar customization and more intuitive movement options.
3. **Semi-structured Interviews:** The interviews provided a more in-depth, qualitative understanding of user experiences. Through detailed personal reflections, the interviews offered nuanced insights into how participants with varied backgrounds perceived immersive technologies. The interviews captured complex emotional and cognitive responses to VR, including fear among novice users regarding visual isolation and disorientation, and concerns about **physical** discomfort and technology-related anxiety. Unlike the surveys and workshops, interviews offered a deeper exploration of users' expectations for future VR applications, including the potential for creative expression and narrative flexibility.

8.4.1.2 Mapping Insights and Behavioural Patterns.

By triangulating these methods, the study revealed several consistent themes and patterns that inform both the design and anticipated user interaction with the IMPULSE VR prototype.

1. **Usability Issues:** The most prominent usability issues across all methods were system instability and slow performance, with significant technical barriers related to crashes, navigation difficulties, and difficulty manipulating content. Participants in the workshops and interviews described unpredictable object behaviours and unclear navigation controls, which detracted from the user experience. These recurring issues across different methods underline the critical need for technical optimization. Addressing these concerns will improve the platform's stability, thereby making it more reliable for real-world use and user testing.
2. **User Expectations:** One key finding across all research methods was users' desire for greater control over the immersive environment. Participants expressed a strong interest in customizing various elements, such as backgrounds, objects, and avatars, to better align the environment with their specific goals. This was especially pronounced among G2, who emphasized the importance of creative expression. Both the workshops and interviews highlighted a need for more dynamic control over the virtual space. Features such as avatar personalization, spatial control, and alternative movement options (e.g., teleportation or flying) were repeatedly mentioned as essential for increasing user agency and enhancing the immersive experience.
3. **Affective and Experiential Insights:** The emotional engagement and narrative aspects of the VR system were identified as key drivers of user engagement, particularly for G1 and G2. For G1 participants, particularly those with limited VR experience, structured educational content and guided navigation were paramount. They expressed a preference for clear, easily navigable systems that could support their educational goals without overwhelming them with complexity. Conversely, G2 participants, with a stronger emphasis on creativity, prioritized artistic freedom and emotional resonance in narrative construction. For G3, the focus shifted to the technical robustness of the platform, with specific emphasis on metadata integration, multi-user collaboration, and curation tools.

8.4.1.3 Differences Between User Groups.

The comparative analysis of G1, G2, and G3 revealed distinct differences in how each group engages with the IMPULSE VR prototype, shaped by their professional backgrounds and digital competences.

1. Group 1:
    a. Key Needs: Clear and structured content, intuitive interface, stability;
    b. Challenges: Technical instability, lack of pedagogical scaffolding tools, beginner user struggles;
    c. Expectations: The expectation for predictable, stable VR environments that could be seamlessly integrated into educational settings.

2. Group 2:
    a. Key Needs: Creative freedom, artistic expression, avatar customization;
    b. Challenges: Limited customization options, absence of tactile feedback, frustration with platform limitations;
    c. Expectations: Flexible storytelling, narrative engagement, and the ability to express creativity through the platform.
3. Group 3:
    a. Key Needs: Metadata support, multi-user functionality, robust content manipulation;
    b. Challenges: Insufficient multi-user options, inability to fully integrate with professional workflows;
    c. Expectations: Reliability, professional-grade tools for curation, exhibition development, and collaboration.

8.4.1.4 Impact of Previous Digital and Cultural Competences.

A key influence on user engagement with the IMPULSE VR system was participants' prior digital and immersive technology experience. The level of exposure to digital tools shaped users' engagement and comfort with the platform, as follows:

- G1 participants, many of whom had limited VR experience, required more instructional guidance and sought educational content that could help them navigate the immersive environment.
- G2 participants, who had more exposure to visual arts and creative practices, engaged more freely with the system, seeking tools that would allow for non-linear interaction and artistic control.
- G3 participants, with strong professional backgrounds in cultural heritage, were more focused on the functional aspects of the system, especially its ability to handle metadata, track provenance, and support multi-user interaction for professional curatorial tasks.

Conclusion

This synthesis and cross-case analysis has provided a detailed understanding of how users from different professional and academic backgrounds interact with the IMPULSE VR prototype. The triangulation of insights from workshops, surveys, and interviews revealed both shared challenges and group-specific expectations that will guide the next steps in the iterative design process. The study highlights the critical need for system stability, customization tools, and improved technical features such as multi-user functionality and interactive narrative options.

Beyond these immediate insights, the triangulated evidence also confirms and operationalises the seven high-level experience goals identified in §5.6: (1) understanding CH environments and context; (2) creating memorable and historically sound experiences; (3) enabling precise inspection and manipulation of CH objects;

(4) narrative-driven storytelling; (5) social co-presence and collaboration (MUVE/IMCo); (6) accessibility and inclusivity; and (7) sustainability and re-use. Each of these goals is substantiated by user evidence: G1 stressed memorability and pedagogical guidance, G2 emphasised creativity and narrative freedom, while G3 prioritised interoperability and robust workflows. This ensures direct traceability from user research to design requirements (§9) and evaluation metrics (§11).

These insights provide clear recommendations for improving the IMPULSE VR prototype in line with user expectations, ensuring that the platform is more inclusive, user-centred, and able to meet the diverse needs of its intended users in the cultural and educational sectors.

8.5 Linking Evidence to Experience Goals

The triangulated evidence from workshops, surveys, and interviews confirms that the seven experiential objectives defined in Section 5.6 are both empirically grounded and practically translatable. The strongest empirical support was observed for objectives related to learning and memorability, narrative-driven storytelling, social co-presence and collaboration, inclusivity, and sustainability of digital assets.

These findings are directly linked to the design implications derived from user research. In this way, the deliverable ensures that the prioritisation of functionalities in WP2 is guided by verified user expectations and behaviours, while WP3 provides the interoperability and standardisation framework needed to sustain these functionalities across contexts.

The analysis of user-proposed functionalities shows that they span different levels of abstraction-from broad experiential concepts to concrete design features. Some form logical or hierarchical relationships that can be visualised as a functionality mapping diagram. Importantly, users were not expected to propose technically feasible solutions but to identify needs and desired outcomes the “building blocks” from which concrete implementations could later emerge.

For example, the request for annotations does not necessarily imply a dedicated annotation module: if the platform supports importing and manipulating multimedia, annotations could be achieved through creative combinations of existing tools (e.g., textures or attached text objects). Such ideas illustrate how user creativity complements the platform’s flexibility once basic stability is ensured.

At later stages, WP1 and WP2 experts jointly refine these proposals, assessing their feasibility and consistency with project scope and resources. This participatory approach combines users’ domain knowledge: educational, curatorial, artistic with the technical expertise of the development teams to identify the most effective design directions.

The current set of functionalities reflects what was feasible at the time of testing, given the early-stage prototype and organisational constraints of the workshops. It represents an interim synthesis of user-derived requirements rather than a final catalogue. The definitive analysis will follow once the complete version of the IMPULSE platform becomes available.

8.5.1.1 Example goal 1. Embodied understanding of CH environments and contexts

Experiential objective (WHY): To enable exploratory and narrative engagement with cultural heritage environments. The platform supports exploratory and narrative-driven engagement with cultural heritage environments. By contextual storytelling we mean narrative scaffolds that embed objects within their spatial, historical, and social frames, thus helping users situate assets in a meaningful interpretive continuum (e.g. Pujol & Champion, 2012; Mortara et al., 2014). This approach is supported by recent works in which authors use contextual storytelling to embed static heritage elements into their cultural, spatial, and narrative worlds (Yu et al., 2025). The system is not intended as a professional-grade GIS or architectural tool, but enables basic spatial orientation and narrative linking of assets to context. By *contextual storytelling* we mean the use of narrative scaffolds that embed cultural-heritage objects within their spatial, temporal, and social contexts, thereby enabling users to situate assets within broader interpretive frameworks.

Operational goals (HOW/WHAT -user-proposed features):

- **World realism -**[Survey G1, G2], (40 responses) -Justification: Realistic representation of space in VR enables a better understanding of the historical and cultural context, allowing users to experience the place in a way that closely resembles reality.
- **Improved graphics and immersion quality** [Survey G1, G2], (3 responses) -Justification: Higher quality of graphics and immersion increases realism, enhancing the sense of "being there" and supporting a better understanding of the environment.
- **Add features to objects** (luminosity, weight, magnetism, spacial sound, accessibility) [Survey Leuven], (1 response) -Justification: Adding physical and sound features allows for a better understanding of the environment's properties as well as its atmosphere and cultural context.
    - [Example of detailed implementation] Adjustment of object brightness (luminosity).
    - [Example of detailed implementation] Addition of transparency and light reflection effects.
    - [Example of detailed implementation] Assignment of weight to objects with visual or haptic feedback, e.g., heavier objects are harder to move, move more slowly, or require multiple users to move them.

- **Export/import, control of lights** [Survey Leuven], (1 response) -Justification: The ability to adjust lighting and work with local files supports the creation of realistic conditions for spatial analysis.

Exploration and perspective

- **Ability to change the way you move** (walking, flying, teleportation) [Survey Leuven], (10 responses) -Justification: Different ways of moving allow for better exploration of space, understanding the relationships between objects, and viewing the environment from different perspectives.
- **Change of scale and perspective** [Interview], [AH01] -Justification: The ability to change scale allows for the analysis of cultural heritage objects in different contexts. For example, viewing a building as a miniature helps to understand its overall structure, while zooming in on details enables the analysis of its decorations. Changing perspective makes it possible to see the object from different viewpoints, which is crucial for understanding its spatial context.
- **Choice of point of view** [Interview], [AH01] -Justification: It gives the user control over how they perceive the virtual environment, allowing for exploration and a better understanding of the space and cultural heritage objects from different perspectives.
    - [Example of detailed implementation] **Switch between predefined viewpoints** (e.g., bird's-eye view, first-person view, object-centered view).
- **Basic navigation in 3D** [default] -*Justification:* Fundamental movement controls allow users to explore cultural heritage environments, understand spatial relationships, and experience the layout of sites before engaging with more advanced features such as perspective changes or behavioural simulations.
    - [Example of detailed implementation] **Walking and turning controls** using controllers, keyboard, or hand-tracking gestures.
    - [Example of detailed implementation] **Smooth locomotion** option for continuous movement for users comfortable with VR navigation.
    - [Example of detailed implementation] **Seated/standing mode adaptation** for accessibility and user comfort.
    - [Example of detailed implementation] **Teleportation mode** for instant movement to selected locations within the virtual environment.
- **Annotation tools linking assets to contextual information** [workshop] -Justification: Annotation tools allow users to link cultural heritage assets with historical or interpretative information, enriching exploration and supporting contextual understanding.
    - [Example of detailed implementation] Adding simple text blocks in the VR space that can be placed next to objects.

- [Example of detailed implementation] Attaching images or scanned documents to blocks with basic scaling and positioning options.
- [Example of detailed implementation] Linking blocks into simple sequences (e.g., text + image + 3D object) to create basic narratives.
- [Example of detailed implementation] Importing PDF/JPG/PNG files as simple contextual elements.
- [Example of dtailed implementation] Moving and rotating blocks in 3D space to align them with the environment layout.

- **Immersive experiences**
  360-degree recordings [Interview], [ST01, GG01] -Justification: 360-degree recordings provide an immersive experience, allowing users to fully immerse themselves in the virtual environment. This enables a better understanding of the spatial context of cultural heritage objects, their relationships with the surroundings, and the atmosphere of the place.
  - [Example of detailed implementation] **Viewing 360° images or videos directly in VR** [Example of detailed implementation] **Basic head-tracking** to allow natural exploration by simply turning the head.
- **headsets** without additional controls.

Behavioural and social analysis

- Analysis of behaviour in simulated social situations [Interview], [KT01] - Justification: VR makes it possible to simulate social interactions in historical contexts. Analysing these interactions allows for a better understanding of social norms, customs, and interpersonal relationships in a given historical period.
  - [Example of detailed implementation] **Simple observation of avatars** moving in a shared VR space.

8.5.1.2 Example goal 2. Creating memorable and historically sound experiences

Experiential goal (WHY):

To create memorable educational and narrative experiences that convey a sense of historical authenticity and plausibility.

Clarification (Scope):

The aim is to foster engagement and narrative credibility rather than to simulate full historiography. This refers to users' perception of authenticity and their sense of meaningful learning, as observed in the empirical studies (Leuven workshop, surveys, interviews).
Any evaluation related to this goal will focus on users' subjective assessments such

as whether they found the experience credible or whether key narrative elements were memorable rather than on formal knowledge testing.

It is important to note that this and similar experiential goals are not formal project objectives as stated in the Grant Agreement. They represent evidence-based recommendations derived from user research and literature review, serving as a conceptual framework for prioritising functionalities in WP2 and for informing future research on immersive cultural heritage.

Operational design goals (HOW/WHAT -user-proposed features):

Creative and educational potential

- **Ability to create and be creative** [Survey G1, G2], (46 responses) -Justification: The ability for creative expression in VR allows users to create personalized experiences, which increases their engagement and facilitates content retention.
  - [Example of detailed implementation] **Placing simple 3D blocks or objects** in the environment to build basic scenes.
  - [Example of detailed implementation] **Changing colors or textures** of selected objects for visual customization.
  - [Example of detailed implementation] **Arranging images or scanned documents** on virtual walls or panels.
- **More educational or professional content** [Survey G1, G2], (7 responses) -Justification: Greater availability of educational and professional content enables the creation of more valuable and reliable historical experiences.
  - [Example of detailed implementation] **Uploading simple PDF or image files** with educational content into the VR space.
  - [Example of detailed implementation] **Embedding short audio explanations** recorded by experts.
- **Support for multimedia cues (audio, images, simple animations) [default] -**Justification: Integrating multimedia elements such as audio narration, historical images, or simple animations enriches the educational and creative potential of VR experiences. They help convey complex information in an accessible way, support learning through multiple modalities, and encourage user engagement by combining visual, auditory, and interactive elements.
  - [Example of detailed implementation] **Placing static historical images** on walls or panels within the VR environment.
  - [Example of detailed implementation] **Adding background audio tracks** (e.g., ambient sounds, simple narrations) to a scene.

Narrative structure

- **Non-linearity and no need to follow rules of reality** [Interview], [AH01] -Justification: The ability to depart from reality allows for the creation of unique historical interpretations that can be more engaging

and memorable. Non-linearity provides the freedom to explore different aspects of history without the need to adhere to strict chronology.
    - [Example of detailed implementation] **Branching story paths** where users choose which part of history to explore next.
    - [Example of detailed implementation] **Overlaying multiple timelines** in the same space (e.g., ruins + reconstructed version).
    - [Example of detailed implementation] **Teleportation portals** to jump between locations or events without realistic constraints.
- **Manipulation of space and time** [Interview], [AH01, GG01, KT01] - Justification: Manipulating time allows for the recreation of historical events and environments, offering users an immersive experience. The ability to change space makes it possible to move to different locations related to a given event or cultural heritage object.
    - [Example of detailed implementation] **Simple zoom in/out option** for a selected object or the entire space.
    - [Example of detailed implementation] **View switch** (e.g., street-level view vs. top-down view).
- **Portals connecting different environments** [Interview], [AH01] - Justification: Moving between different places and times enriches the experience, allowing users to "travel" through time and space. Portals can connect different cultural heritage environments, creating a coherent and engaging narrative.
- **Virtual tours and historical reconstructions** [Interview], [GG01, KT01] - Justification: Virtual tours and reconstructions bring history to life, allowing users to "touch" the past. This makes it possible to better understand and remember historical events and the associated cultural heritage objects.
    - [Example of detailed implementation] **Option to upload 3D models** of historical objects into the tour.
    - [Example of detailed implementation] **Scaling tool** to adjust the size of uploaded objects for realistic proportions.
- **Narrative scaffolding** [worshops] -Justification: Narrative scaffolding provides structural cues, such as timelines, story maps, or interactive prompts, that help users follow the storyline and understand its context without restricting exploration. It supports historical plausibility and knowledge retention by linking immersive experiences with key narrative elements, ensuring that users can navigate complex stories while maintaining engagement.
    - [Example of detailed implementation] **Story checkpoints** that highlight main moments or decisions *-implemented as simple textures placed on basic blocks in the environment*.

Environment editing and customization

- **Ability to edit the VR environment** [Survey Leuven], (16 responses) -Justification: Editing the environment allows for the reconstruction of historical scenes and the creation of visually engaging narratives.
- **Additional editing options and customisation of assets** [Survey Leuven], (1 response) -Justification: Greater editing capabilities allow for a more accurate reconstruction and interpretation of the historical context.
- **Advanced options of interaction with exhibits** (e.g. swarm motion, 2D→3D) [Survey Leuven], (1 response) -Justification: Advanced interaction options enable a deeper understanding of artifacts and their presentation in an engaging, multimedia form.

8.5.1.3 Example goal 3. Inspection and manipulation of CH objects

Experiential goal (WHY):

Ensuring intuitive inspection and comparison of cultural heritage objects.

Clarification (Scope):

The goal is to enable intuitive inspection and comparison of objects. The platform does not replace professional 3D modelling or CAD tools.

Operational design goals (HOW/WHAT -user-proposed features):

Ease of use

- **Intuitive controls and ease of use** [Survey G1, G2], (57 responses) + Easier to use (1 response) -Justification: Intuitive object controls allow users to freely explore and analyse them, supporting detailed inspection of cultural heritage. Simplifying VR operation lowers the entry barrier and enables users to focus on analysing objects rather than dealing
- with complex technology.
    - [Example of detailed implementation] **Ability to grab and move an object** -users can select an object with a simple gesture or button press and reposition it freely in the virtual space.

Direct interaction with objects

- **Basic navigation in 3D [default] -**Justification: Fundamental movement controls allow users to approach, position themselves around, and orient cultural heritage objects before performing detailed inspection or manipulation. Without basic navigation, other interaction features such as zooming or rotating would be limited in practical use.
- **Intuitive interaction via hand tracking** [Interview], [AH01, MA01] -Justification: Natural interactions make it easier to manipulate objects

in the virtual environment. Hand tracking enables precise grabbing, rotating, and analyzing of cultural heritage objects, which is particularly useful in research and education.

- **Zoom, rotate, scale** [default] -*Justification:* Basic object manipulation tools such as zooming, rotating, and scaling provide essential capabilities for examining cultural heritage objects from multiple perspectives and at various levels of detail.
- **Copying and scaling objects** [Interview], [AH01] -Justification: Duplicating and scaling allows for a better understanding of the structure and details of objects. Virtual copies of cultural heritage objects can be created and made accessible to a wider audience without risking damage to the originals.
- **Changing scale and perspective** [Interview], [AH01] -Justification: Zooming in and out facilitates the analysis of details. Changing the scale makes it possible to view the object in different contexts and from various perspectives.

Collaboration and experimentation

- **Collaborative 3D modelling and simulations** [Interview], [KT01, MA01] -Justification: Collaborative creation of 3D models supports a better understanding of objects. Users can work together on creating virtual reconstructions of cultural heritage objects, sharing knowledge and experience.
- **Manipulation of space and time** [Interview], [AH01] -Justification: Manipulating time and space can help analyze objects from different perspectives, for example, how they have changed over the years.

Advanced editing

- **Copying objects, changing speed, platform stability** [Survey Leuven], (1 response) -Justification: Duplicating objects, changing their motion dynamics, and ensuring system stability are essential for precise research work with digital resources.
- **Ability to edit content, import/export** [Survey Leuven], (1 response) -Justification: The ability to work with files and edit content enables detailed analysis of objects as well as their modification for research purposes.
- **Additional editing and customisation options** [Survey Leuven], (1 response) -Justification: Personalization and editing of objects allow researchers to tailor visualizations to their own analytical needs.
- **Metadata and paradata overlays** [default] -*Justification:* Displaying metadata (e.g., object provenance, dating, source) and paradata (e.g., reconstruction assumptions, uncertainty levels) directly on or alongside the object supports informed analysis and transparency in cultural heritage interpretation.

8.5.1.4 Example goal 4. Narrative structuring and storytelling.

Experiential goal (WHY):
Supporting educational and creative narratives with the possibility of content re-use.

Clarification (Scope):

The platform facilitates **layered narratives** for education, creativity, and re-use, rather than professional authoring pipelines.

Operational design goals (HOW/WHAT -user-proposed features):

- **Non-linearity and no need to follow rules of reality** [Interview], [AH01] -Justification: Non-linearity provides freedom in constructing stories, allowing for the creation of interactive and engaging narratives.
- **Manipulation of space and time** [Interview], [AH01] -Justification: Changing the temporal and spatial perspective can enrich the narrative, allowing stories to be told from different viewpoints and in various contexts.
- **Portals connecting different environments** [Interview], [AH01] -Justification: Portals can serve as elements connecting different narrative threads, creating a coherent and engaging story.
- **Choice of point of view** [Interview], [AH01] -Justification: The choice of perspective influences how the story is perceived, allowing users to identify with different characters and understand their motivations.
- **Multi-user co-narration [default]** *-Justification:* Allowing multiple users to collaboratively create and narrate stories in real-time enriches the narrative experience with diverse perspectives, fosters creativity, and supports educational dialogue within shared cultural heritage environments.

8.5.1.5 Example goal 5. Social co-presence and co-creation (MUVE).

Experiential goal (WHY):

Supporting collaborative learning and co-creation of content in the VR environment.

Clarification (Scope):

The aim is to support collaborative learning and co-creation, focusing on session management, role allocation, and shared annotations, without aspiring to large-scale MMO features.

Operational design goals (HOW/WHAT -user-proposed features):

Quality of interaction

- **High-quality social interactions** [Survey G1, G2], (19 responses) -Justification: High-quality social interactions enable realistic collaboration in VR, allowing users to jointly explore and create content related to cultural heritage.
- **Enhanced communication options** (chat, video, emojis, nonverbal cues) [Survey Leuven], (7 responses) -Justification: Advanced communication options enhance the realism of social interactions and enable more complex collaboration.
- **Voice/chat tools** [workshops] -*Justification:* Providing both voice and text communication options ensures flexible and effective real-time collaboration, accommodating different user preferences and accessibility needs. Can be implemented via connecting external tools such as Discord.

Identity and presence

- **Ability to personalise avatars** [Survey Leuven], (8 responses) -Justification: Avatar personalization supports a sense of identity and presence in the social environment, which is essential for collaboration.
- **Collaboration**
- **Collaborative 3D modelling and simulation**s [Interview], [MA01, KT01] -Justification: It enables collaboration on projects in the virtual environment [ZV01, KT01, MA01]. Users can jointly create 3D models, simulate historical events, and share knowledge and experience.
- **Shared annotations** [workshop] -*Justification:* Allowing users to annotate scenes and objects collaboratively enhances co-creation and shared understanding during group exploration or project work.
- **Session recording/replay** [workshop] -*Justification:* Recording and replaying collaborative sessions supports reflection, learning analytics, and documentation of group work for future reference.

Knowledge sharing

- **Knowing more about tools and best practices** [Survey G1, G2], (1 response) -Justification: Better knowledge of available tools supports effective collaboration, as users can more easily share content and use appropriate features.
- **Collaboration management**
- **Role-based access control** (admin/creator/observer) [default] -*Justification:* Assigning roles ensures structured collaboration, supports moderation, and allows for differentiated user experiences (e.g., guided tours vs. open exploration).

8.5.1.6 Example goal 6. Accessibility and inclusivity

Experiential goal (WHY):

Ensuring basic accessibility and inclusivity for a wide range of users.

Clarification (Scope):

The platform ensures basic accessibility compliance across devices. It complements but does not replace specialist assistive technologies.

Operational design goals (HOW/WHAT -user-proposed features):

Lowering barriers to access

- **Cheaper and easier access** [Survey G1, G2], (20 responses) -Justification: Lower cost and easier access to VR make it easier for people from diverse backgrounds to use the technology.
- **Free trial options** [Survey G1, G2], (1 response) -Justification: Free trial versions increase accessibility and allow potential users to evaluate the value of VR before investing in equipment.

Broadening access to experiences

- **Access to contexts not otherwise accessible** [Survey G1, G2], (1 response) -Justification: VR enables the exploration of places inaccessible due to geographical, financial, or health reasons, thereby increasing inclusivity.
- **Access to educational and professional content** [Survey G1, G2], (21 responses) -Justification: Providing access to educational and professional content supports equal opportunities and the dissemination of knowledge.
- **Virtual tours and historical reconstructions** [Interview], [GG01, KT01, ZV02] -Justification: It enables access to physically inaccessible places. People with disabilities, elderly individuals, or those living in remote locations can visit cultural heritage sites without the need for travel].

Accessibility tools

- **Ability to edit VR environment and add accessibility features** [Survey Leuven], (1 response) -Justification: Introducing accessibility tools allows people with diverse needs to participate in VR experiences on equal terms.

8.5.1.7 Example goal 7. Sustainability and re-use of digital CH assets

Experiential goal (WHY):

Promoting the re-use and interoperability of digital cultural heritage resources.

Clarification (Scope):
The system promotes **interoperability and re-use** of assets and outputs in line with ECCCH guidelines. It is not a full-scale repository but supports exchange and integration.

Operational design goals (HOW/WHAT -user-proposed features):

Interactive engagement

- **Interactive content presentation** [Interview], [KT01] -Justification: Interactivity increases user engagement and the re-use of resources [30]. Users are more likely to return to virtual cultural heritage environments if they offer interactive and engaging experiences.
- **Creating interactive environments** [Interview], [GG01] -Justification: Interactive environments encourage repeated engagement with virtual heritage. Users can explore, experiment, and create their own interpretations of cultural heritage objects, increasing their involvement and motivation for further exploration.
- **Gamification** [Interview], [GG01] -Justification: Game elements increase engagement and motivate further exploration. Gamification can be used to create interactive quizzes, challenges, and rewards that encourage users to re-engage with virtual heritage.
- **Virtual galleries** [Interview], [GG01] -Justification: Virtual galleries make resources available to a wider audience. Users can visit virtual galleries from anywhere in the world, increasing accessibility and the re-use of digital cultural heritage resources.

Intuitive interaction

- **Intuitive interaction via hand tracking** [Interview], [AH01, MA01] -Justification: Intuitive interaction increases user engagement, leading to more frequent and effective use of digital cultural heritage resources.
- **Reusability and preservation**
- **Copying and scaling objects** [Interview], [AH01] -Justification: Virtual copies protect original objects, allowing them to be studied and presented without the risk of damage.
- **Export/import functionality, control over light** [Survey Leuven], (1 response) -Justification: The ability to re-use and modify resources increases their longevity and opens the way for multiple applications across different projects.
- **Copyright and licensing metadata for uploaded objects** [default] -Allow users to define copyright status, licenses (e.g., CC BY, CC BY-NC), and usage permissions for uploaded 3D objects and media files to ensure legal clarity and ethical re-use.

9 User Evidence in Relation to Functional Requirements: Authoring / Experiencing / Community (MUVE/IMCo)

This chapter analyses how the high- and low-level experience goals defined in Section 5.6 relate to the functional domains of the IMPULSE platform. It presents user evidence relevant to Authoring, Experiencing, and Community (MUVE/IMCo), consolidating empirical findings that help interpret and support the understanding of functional requirements already established in WP2.

Rather than redefining the platform's architecture which has already been outlined in earlier project stages this chapter organises user-derived insights into a transparent mapping between experience goals, user needs, and corresponding design signals. It thus provides a structured overview of three domains (Authoring, Experiencing, Community) and illustrates how empirical evidence from workshops, surveys, and interviews can inform ongoing development and evaluation.

Implementation feasibility will depend on WP2's prioritisation under Task 2.3, as well as technical constraints and alignment with the project's scope and resources. Not all user-identified expectations can be realised within the current framework; instead, they serve as an evidence base for future prioritisation and for informing subsequent iterations of immersive cultural heritage platforms.

By organising requirements across the three domains, the chapter provides a structured framework that supports **reflection, prioritisation, and traceability**, while making explicit the boundaries of the IMPULSE platform. The system is conceived as an exploratory and co-creative environment, enabling learning, storytelling, and collaborative engagement with cultural heritage. Advanced professional-grade features (e.g. high-fidelity modelling, GIS-level simulations) **remain beyond the project's scope and are presented as recommendations for future work.**

Scope

In scope: core user interactions (e.g.: importing objects and textures, adjusting object size, modifying position and orientation), their boundaries and interactions; constraints observed in the Leuven prototype; direction-of-travel requirements for the next iterations.

Out of scope: detailed technical implementation notes and vendor-specific considerations (addressed in WP2 documentation).

Structure of the chapter

§9.1 provides an overview across the three domains;

§9.2-§9.4 specify each domain in detail;

9.1 Functional Overview

This section consolidates the functional snapshot of the Leuven prototype into three categories of **requirements** (Authoring, Experiencing, and Community) and highlights the immediate implications for the next iterations. It distinguishes between the baseline observed in Leuven and the direction of travel derived from user evidence and the low-level goals.

A. Authoring (create, structure, enrich)

Baseline observed (Leuven):

- asset intake: import of 2D images (.jpg/.png) and 3D models; images could be projected onto simple 3D primitives (boxes, cylinders, spheres). 3D asset integration was not extensively exercised because the available workshop archives were mostly images.
- scene composition: basic spatial placement in a virtual room; simple operations (e.g., background colour change, delete).
- content enrichment: no in-scene metadata/annotation visible to others; no paradata capture; no lighting/audio authoring.

Direction of travel (requirements signal):

a robust asset pipeline (2D/3D) with clear format support and graceful handling of large files was consistently requested by users. Within IMPULSE, this will be addressed at a baseline level, while advanced optimisation (e.g. handling multi-GB 3D models) is recognised as a future requirement beyond the project's scope.

narrative authoring scaffolds (linear/branching/layered), reusable didactic templates, and annotation/paradata binding at object and scene level. These can inform WP2 prototyping, while more advanced scripting/timeline tools are identified as desirable for subsequent development.

basic media authoring affordances (lighting / audio cues) sufficient for pedagogical and curatorial scenarios are expected within the project scope. Advanced lighting features (e.g. reflections) are recognised as valuable but resource-intensive and may be left to future iterations. Spatialised audio, as confirmed by WP2, will be implemented and may support storytelling elements.

B. Experiencing (navigate, inspect, understand)

Baseline observed (Leuven):

- navigation & locomotion: keyboard/mouse (desktop) or VR controllers; movement limited to basic directional input; no teleportation or free-fly; interaction logic sparsely documented, causing confusion for some participants.
- object interaction was limited to basic placement and manipulation at scene level; users lacked tools for detailed inspection (e.g. zooming, rotation, layered metadata), and therefore no consistent workflow for close examination emerged.
- representation: generic avatars present but with no expressiveness relevant to user perception during solo use.

Direction of travel (requirements signal): exploratory recommendations based on user evidence)**:**

- **Ease of orientation in 3D.** User research (Leuven workshop, §8.1.6) revealed that several participants, especially in G1, experienced confusion with navigation controls and spatial orientation. To address this, users suggested clearer orientation cues (e.g. visual markers, optional mini map, or guided-tour mode). These are indicative improvements rather than full-fledged GIS or museum-navigation features.
- **Inspection and manipulation of CH objects**. Participants in all groups expressed the desire to interact more directly with heritage assets (zoom, rotate, compare), and to access contextual metadata. Artists (G2) and educators (G1) in particular valued the idea of attaching simple narrative layers (e.g. sequential images, audio commentary, basic branching). These should be understood as lightweight scaffolds for exploratory engagement, not as complex scripting or professional-grade authoring tools.
- **Onboarding and tutorials.** Novice users (mainly G1) highlighted difficulties in understanding how to start interacting with the environment. While the learning curve was not considered steep, participants asked for introductory guidance. Short text or video tutorials are a feasible response within scope.
- **Accessibility.** In line with the GA, accessibility here refers to expanding virtual access to digitised CH collections. Broader accessibility features (e.g. screen readers, assistive technologies for disabilities) are recognised as important but fall outside IMPULSE's scope. Some participants nevertheless indicated interest in captions or audio narration to support inclusivity, which could be considered in a lightweight form.

Clarification on scope: These recommendations are derived from user research and indicate directions for future improvement. They are not mandatory requirements

for WP2. Within IMPULSE, only a subset of these elements may be prioritised for implementation, while others remain reference points for future projects or follow-up initiatives.

C. Community (MUVE/IMCo: co-presence, roles, collaboration)

Baseline observed (Leuven):

- **co-presence:** synchronous multi-user sessions were available, though occasional connection failures (common in any networked system) limited participation for some users.
- **avatars & social cues:** the prototype offered only generic, non-customisable avatars, without gesture/facial expressiveness or presence indicators.
- **collaboration infrastructure:** role management, shared annotations, moderation tools, and session recording were not available at this stage.

Interpretive note:
While these limitations were clearly perceived by users, they should be understood as *future-facing guidelines* rather than direct WP2 obligations. Some aspects (e.g. stability improvements, basic avatar refinements) can be incrementally addressed, but more advanced CSCW-style features (role hierarchies, moderation dashboards, rich expressiveness) fall outside the IMPULSE scope and are identified here as recommendations for subsequent projects.

Direction of travel (requirements signal):

Direction of travel (exploratory recommendations based on user evidence):

role-based MUVE. In the Leuven workshop and interviews (§8.1.7, §8.3.3), participants repeatedly highlighted the importance of clearly defined roles in multi-user sessions (e.g. guide/teacher, participant/student, curator/visitor). This reflects pedagogical and curatorial expectations of structured collaboration. Within IMPULSE, such role-based interactions may be considered in a lightweight form (e.g. basic permissions or turn-taking), while more advanced features remain outside the GA scope.

session services. Several users expressed interest in functionalities such as asynchronous access, session replay, or shared annotations. These are aspirational directions that could significantly enrich collaboration but are unlikely to be fully implemented within the timeframe and resources of IMPULSE. They should therefore be documented as reference points for future projects.

presence & safety. Participants underlined the need for trust and moderation in shared spaces. Suggested measures included simple expressiveness cues (gestures, emojis), basic chat/voice options, and privacy/safety

controls. Within IMPULSE, only a minimal subset of these may be implemented; more complex solutions are beyond scope but are recorded here as evidence of user priorities.

Clarification on scope: These recommendations summarise user expectations but do not imply that all features will be implemented in WP2. They serve as an evidence base for prioritisation and as input for future research and development initiatives beyond IMPULSE.

Cross-cutting considerations (all domains, evidence-based):

performance & stability. User feedback consistently highlighted frustrations with system crashes and lag, particularly when handling larger assets or multi-user sessions (§8.1.7, §8.3). While these technical limits are inherent to current VR hardware, the concern is documented here as a critical baseline requirement for reliable experiences.

interoperability & re-use. Users (esp. G3) emphasised the importance of workflows that allow assets, metadata, and paradata to remain usable across contexts. In IMPULSE this does not imply full platform-level interoperability (which is beyond scope), but rather:

consistent metadata handling in the repository and VR client (as already foreseen in WP3),

potential linking with existing CH infrastructures such as Europeana,

basic affordances for re-use of content and annotations across scenarios.

These are aligned in a broad sense with ECCCH ambitions, but without prescriptive technical commitments.

accessibility & inclusivity. In the proposal and GA, accessibility was framed primarily as *widening access to CH collections* rather than implementing full WCAG-compliant assistive features. Evidence from surveys (§8.2) nevertheless highlights user expectations around inclusive access (e.g. multilingual captions, simplified onboarding). Within IMPULSE, this remains a recommendation for future work, not a requirement for WP2 implementation.

evidence & pathways for future development The evidence gathered through WP1 provides a coherent empirical basis for understanding how user needs translate into functional and experiential priorities. While not assigning indicators to specific functionalities, it establishes a transparent framework that supports reflective evaluation and lays the groundwork for methodological re-use in future projects on immersive cultural heritage.

Clarification: These cross-cutting concerns summarise recurring themes from user research and from the state of the art. They do not expand the technical scope of WP2

but highlight areas where IMPULSE evidence may inform prioritisation and future initiatives beyond the project.

Sections 9.2-9.4 specify the detailed requirements per domain (describing user expectations, not the requirements imposed on the IMPULSE platform in this project). Implementation feasibility will depend on WP2's prioritisation and technical constraints; not all user-identified needs can be realised within IMPULSE's scope, budget, or timeline.

9.2 Authoring (create, structure, enrich)

Scope and roles. Authoring covers all tools used to ingest assets, compose scenes, design narratives, and publish sharable experiences. Typical roles include Educator/Teacher, Curator/CH Professional, Artist/Creative Practitioner, and, optionally, Reviewer/Moderator. Authoring outputs are re-usable scenes, narrative templates, and packs (assets + metadata + paradata), consumable in Experiencing and Community domains.

Rationale (link to WHY & evidence).

- Supports Narrative-driven storytelling, Understanding CH environments, and Sustainability & re-use by enabling structured, credible, and reusable content (WHY §5.6).
- Responds to user needs identified in Leuven workshop (request for flexible narrative tools), surveys (onboarding and clarity), and interviews (workflow integration for G3; creative latitude for G2) (Chapter 8).

9.2.1 Asset intake & management

User expectations consistently pointed to the importance of smooth integration of cultural-heritage assets into immersive scenes. While IMPULSE does not develop a professional 3D modelling tool, the following baseline directions emerge from research:

import and validation. Users expect support for importing standard 2D/3D formats and receiving clear feedback in case of errors. This is framed as basic usability, not advanced modelling.

provenance and metadata. Consistent with WP3 objectives, users stressed that every imported asset should retain information on source, creator, rights, and date. This is key for trust and re-use.

optimisation and performance. Some users suggested lightweight handling of larger assets (e.g., previews, simplified representations). While full optimisation pipelines are out of scope, this remains a recommendation for future work.

repository connections. Linking to existing CH aggregators (e.g., Europeana, IIIF/EDM endpoints) was seen as desirable, especially for G3 professionals. Within IMPULSE this may be feasible at the level of lightweight connectors or plugins, not full integration.

9.2.2 Scene composition & layout

Across workshops and interviews, users expressed a strong preference for intuitive scene construction tools. While IMPULSE does not aim to replicate the affordances of a professional 3D engine such as Unity, several baseline directions emerged:

ease of placement. Users expect simple drag-and-drop placement of objects and basic manipulation (move, rotate, scale). This is seen as fundamental for accessibility and pedagogical usability.

scene organisation. The idea of a layered scene structure (e.g., background, objects, interface, narrative cues) was repeatedly mentioned as a way to manage complexity. Visibility toggles were considered desirable but not essential.

templates and re-use. Some participants proposed the availability of reusable layouts or presets for typical didactic or curatorial scenarios. While this is outside the immediate scope of development, it remains a useful recommendation for future extensions.

constraints and collision. Users highlighted the value of simple constraints (collision detection, bounding boxes) to avoid object overlap and maintain spatial realism. Basic collision is already foreseen in WP2 implementation; more advanced auto-layout functions are beyond current resources.

Clarification: These points summarise user expectations. They should be read as an **evidence-based reference, not as mandatory requirements for WP2**. Actual implementation will be prioritised according to project scope, resources, and technical feasibility.

9.2.3 Narrative authoring (linear/branching/layered)

User research consistently highlighted the value of structured storytelling tools to enhance memorability and engagement. While IMPULSE does not aim to provide a full-fledged narrative engine, several directions emerged:

basic guided tours. Participants valued simple authoring flows such as stepwise tours with waypoints, time pacing, and voice or text prompts. These affordances were seen as highly relevant for educational and curatorial contexts.

narrative layering. Users suggested that narratives might benefit from multiple layers (e.g., factual, pedagogical, creative), ideally switchable

by the audience. While this is beyond the immediate development scope, it remains an important recommendation for future platforms.

branching or conditional storytelling. Some participants expressed interest in branching structures or interactive triggers, but acknowledged that these would require significant additional functionality not foreseen within IMPULSE.

versioning. The idea of maintaining multiple versions of storylines (e.g., scholarly vs. public audiences) was also raised, but this is considered out of scope for the current project and instead provides guidance for future initiatives.

Clarification: These elements are included here to document user expectations and to inform future design guidelines. Within IMPULSE, WP2 will prioritise only the most feasible elements (e.g., simple guided tours), while advanced features remain recommendations beyond current resources.

9.2.4 Annotation, metadata & paradata binding

User feedback consistently emphasised the importance of being able to contextualise cultural heritage (CH) assets through annotations and metadata. However, expectations vary in complexity, and only a subset is feasible within IMPULSE:

Implemented or supported within the current IMPULSE framework

simple object-and scene-level text annotations, with potential for visibility settings (public/private).

basic metadata capture, including at least provenance and ownership information.

audio spatialisation already supported in the VE, enabling annotations in the form of audio cues or narratives.

Recommendations for future development

Based on user research and empirical evidence collected in WP1, several advanced functionalities have been identified as desirable directions for the future evolution of immersive cultural heritage platforms:

Extensible metadata and paradata schemas (tracking *who*, *when*, and *why* changes were made; including method and parameter records).

Richer linking of references (e.g. bibliographies, authority files) to enhance content credibility and traceability.

Export of annotations into interoperable formats (JSON/CSV) to facilitate data exchange and re-use.

In-situ citations and review workflows (e.g. footnote pins, collaborative editing environments) supporting transparent knowledge production.

Clarification: Within IMPULSE, only lightweight annotation and provenance features are foreseen. The additional capabilities described above represent user-driven

expectations and long-term recommendations, intended to inform future guidelines and platform development beyond the current WP2 scope, not as binding project requirements.

9.2.5 Templates for pedagogical and curatorial use

User research (particularly from G1 educators and G2 practitioners) highlighted a strong interest in structured pathways to support teaching, learning, and curatorial storytelling. Participants suggested templates that could simplify scene construction and provide reusable pedagogical or exhibition scenarios. Implemented or supported within the current IMPULSE framework.

Feasibility within the current IMPULSE framework

Within the present technical framework of IMPULSE, only lightweight sequencing and instructional elements can be supported. These include:

- waypoint-based guidance for structuring exploration (e.g., predefined "stops" in a scene);
- the ability to embed short prompts or instructions linked to specific objects or locations.

Recommendations for future development

Based on user feedback, several directions for future immersive CH platforms have been identified:

- **didactic templates** supporting inquiry-based learning or comparative analysis, potentially including simple assessment features;
- **curatorial templates** enabling thematic or narrative trails (object paths, thematic reconstructions) enriched with metadata and contextual notes;
- **creative templates** for G2 users, facilitating hybrid artistic-educational scenarios through speculative or comparative narrative structures.

Clarification: IMPULSE does not aim to deliver a comprehensive e-learning or exhibition-authoring system. The project's scope includes only lightweight sequencing and guidance mechanisms. The more advanced template-based authoring systems discussed above are documented as *evidence-based recommendations* to inform the design of future immersive cultural heritage platforms.

9.2.6 Publishing, versioning & export

User research (particularly from G3 professionals and G1 educators) emphasised the importance of being able to **save, re-use, and share authored immersive environments**, as these functions directly support teaching, curation, and iterative creative work. Participants underlined that without persistent saving and loading, immersive experiences risk being limited to "one-off" events with no continuity

or institutional reuse. The capacity to reopen, adapt, and exchange authored scenes was repeatedly linked to the long-term sustainability and value of the IMPULSE platform.

Implemented or supported within the current IMPULSE framework

- Reliable saving and loading of authored scenes, including assets and metadata already supported within the repository.
- Draft and publish modes allowing users to store incomplete work and return to it later.
- Basic version history (previous save states) enabling recovery from errors or iterative editing.
- Scene export and import mechanisms preserving metadata and structure, ensuring interoperability with WP3 standards.

These functionalities fall within the realistic technical scope of IMPULSE and directly address user needs identified in workshop (Leuven) and surveys, ensuring continuity of creative and educational work.

Recommendations for future development

Based on empirical findings from WP1, several advanced features have been identified as desirable for the future evolution of immersive cultural heritage platforms:

- Full version control with paradata tracking (who, when, and why changes were made).
- Advanced export/import packages with attribution rules, remix settings, and interoperability with external repositories (e.g. IIIF, Europeana).
- Offline or installation-ready packages for classrooms and pop-up exhibitions, ensuring accessibility in low-connectivity contexts.
- Integration of collaborative review and publish workflows for multi-author editing and transparent versioning.

Clarification

Within IMPULSE, the focus will remain on robust save/load functionality and metadata persistence. Advanced features-such as full paradata integration, remix governance, and offline deployment kits-are recognised as valuable user-driven expectations but lie outside the current WP2 implementation scope. They are included here to inform future guidelines and design recommendations for sustainable immersive cultural heritage infrastructures.

9.2.7 Usability, onboarding & safeguarding

User research (especially G1 and G3) stressed the importance of saving and re-using authored environments for teaching, curation, and iterative creative work. Participants emphasised that without such functionality, immersive scenarios risk being “one-off” and not reusable.

Implemented or supported within the current IMPULSE framework

draft/publish states enabling users to save incomplete work and return later.

scene saving/loading with associated assets and metadata (already supported via repository functions).

basic version history (previous save states), at least locally, to allow recovery from errors.

Recommendations for future development.

full version control (restore points, branching histories) with paradata (who/when/why).

advanced export/import packages with attribution rules, remix settings, and interoperability with external repositories (e.g., IIIF/Europeana endpoints).

offline/installation kits for classrooms or pop-up exhibitions, ensuring access in low-connectivity contexts.

Clarification: For IMPULSE, the focus will remain on robust saving/loading and metadata persistence. More advanced features (full paradata integration, remix governance, offline kits) are beyond current project scope but are documented here to inform future immersive CH infrastructures.

Non-functional (Authoring).

Performance: smooth import and save processes for typical scene sizes; editing should remain responsive under realistic asset counts. Indicators will be monitored in the evaluation framework (§11) rather than specified as strict benchmarks.

Reliability: autosave and recovery mechanisms to reduce data loss in case of crashes.

Compliance: prompts for rights/attribution, and data minimisation principles for user logs (see WP4).

Interoperability: export schemas aligned with WP3's simplification work, with persistent identifiers to support future reuse.

Clarification: These requirements summarise recurrent user concerns (Leuven workshop, surveys, interviews) and KE review points. They are intended as design guidelines and evaluation signals, not binding technical specifications.

9.3 Experiencing (navigate, inspect, understand)

Scope and roles. *Experiencing* covers how participants (students, visitors, collaborators) enter, navigate, and interpret authored content in solo or guided modes. It implements the **user-facing interaction layer** -that is, the set of perceptual and interactive features

(navigation, manipulation, guidance) that transform authored material into meaningful cultural-heritage experiences.

Rationale (link to WHY & evidence).

- delivers understanding of ch environments, memorability, accessibility & inclusivity, and co-presence (when guided).
- addresses navigation difficulties, onboarding needs, and desire for precise object inspection evidenced across workshop, surveys, interviews (Chapter 8).

9.3.1 Wayfinding & locomotion

- **Core support (to be implemented where feasible):** at least two basic locomotion modes (e.g., teleportation and continuous walk) with adjustable speed/turning options; snap-turn on VR devices; WASD navigation on desktop.
- **Recommended enhancements (future or exploratory):** wayfinding aids (breadcrumbs, highlights, optional minimap), configurable hotspots/waypoints for tours, and a simple guided mode (follow-the-guide or regroup button).
- **Longer-term guidelines (beyond IMPULSE scope):** contextual beacons (visual/audio task cues) and path recording for replay.

9.3.2 Object inspection & manipulation

- **Core support (implemented or supported within the current IMPULSE framework):** users consistently expected intuitive object handling (grab, rotate, zoom) with simple reset-to-neutral controls. Metadata-on-demand (e.g., title, origin, rights) was highlighted as a key requirement for credibility.
- **Recommended enhancements (user evidence, but future-oriented):** richer inspection tools (side-by-side comparison, overlay, or scale/measurement aids) and the option to bookmark states for later reference. These features are desirable but may exceed current technical priorities.
- **Guidelines for further projects:** time-based object states (e.g., reconstructions, alternative hypotheses) could expand interpretive depth in future VR heritage platforms.

9.3.3 Narrative consumption & pacing

- **Core support (feasible within project scope):** simple multi-layer presentation of narratives (e.g., factual information with optional educator/curator commentary), with basic user pacing controls (pause, resume, skip). Text-audio-visual synchronisation and basic readability (contrast, font size, UI scaling) are prioritised for inclusivity.

- **Recommended enhancements (future-oriented):** branching narrative options with visible consequences, and checkpointing to allow users to resume where they left off.
- **Guidelines for longer-term development (beyond current scope):** adaptive sequencing (simplifying or adjusting pathways if user confusion is detected) and personalised narrative tracks (novice vs. expert).

9.3.4 Onboarding, guidance & help

- **Core support (within IMPULSE scope):** user evidence consistently indicated the need for a first-run tutorial to familiarise newcomers with core controls, comfort settings, and safety precautions. This can be realistically implemented through simple **text-or video-based tutorials**. Participants also valued contextual help (tooltips, hints) and the ability to recover from errors (undo, reset position).
- **Recommended enhancements:** in guided sessions, an instructor/guide HUD could support pace control and direct participants' attention (e.g., spotlight, ping).
- **Future-oriented guidelines:** self-check micro-assessments (such as "find the date on the artefact") could provide feedback loops and support learning analytics, but are outside the current scope of IMPULSE.

9.3.5 Accessibility & inclusivity (evidence-based user needs, within IMPULSE scope and beyond)

- **Core support (realistic within scope):** user testing showed that comfort settings (e.g., vignette, snap-turn, locomotion choice), adjustable UI scale, and a high-contrast theme are essential for reducing discomfort and ensuring broad usability. These are aligned with baseline accessibility in immersive systems and can be realistically implemented.
- **Recommended enhancements (future-oriented):** captioning/subtitles for audio, audio description for key visuals, and remappable controls were frequently mentioned as desirable, but they go beyond the current technical and resource scope of IMPULSE. They are therefore noted here as **guidelines for future projects**.
- **Additional options:** language localisation of core UI and support for both seated and standing modes could increase inclusivity, though these may be implemented selectively depending on feasibility.

9.3.6 Feedback, presence & safety (user priorities; phased feasibility)

- **Core support (realistic within IMPULSE scope):**
  -immediate feedback on basic interactions (e.g., visual or simple audio confirmation of actions).

-clear system status indicators (loading, saving, joining/leaving sessions).
-basic presence cues in guided sessions (e.g., nameplates, speaking indicator).
-simple moderation and safety controls (mute, remove/report).

- **Recommended enhancements (future-oriented, guidelines only):**
  -session quality indicators (latency, packet loss) visible to guides/facilitators.
  -regroup function for synchronous sessions.
- **Optional future enrichment:**
  -lightweight presence signals (e.g., gestures, emotes) provided they respect privacy and do not overload the system.

Non-functional (Experiencing).

- performance: target frame-rate and motion-to-photon latency bands for comfort (to be set in §11 per device class).
- reliability: graceful degradation under network/load; offline fallback for single-user experiences where feasible.
- privacy & data protection: minimal necessary telemetry; clear consent flows (see WP4 description).
- **internationalisation (guideline-level):** The platform's core UI should remain language-neutral where possible (icons, universal symbols). Where feasible, a lightweight localisation strategy for priority languages can be considered. Full multilingual support is outside the project scope but is recommended as future work for wider uptake.

9.4 Community (MUVE/IMCo: Co-presence, Roles, Collaboration)

The "Community" domain encompasses all features that enable co-presence, collaboration, and community animation across synchronous and asynchronous modes: roles and permissions, communication, moderation and safety, session recording and replay, shared artefacts (annotations, narratives), and community management functions (IMCo). The purpose is to translate high-level goals (co-presence and collaboration; accessibility and inclusion; sustainability and re-use) into actionable requirements for WP2-WP5.

Rationale (WHY & evidence).

User research (Leuven workshop, surveys, and interviews) consistently highlighted the demand for multi-user sessions, clearly defined roles (e.g. teacher-student, curator-visitor), reliable communication, and shared outcomes. Professionals (G3) stressed workflow stability and provenance traceability, educators (G1) emphasised guided control of group pace, while artists (G2) sought flexible modes of co-creation.

Findings from the Leuven workshop, surveys, and interviews consistently highlighted the demand for multi-user sessions, clearly defined roles (e.g. teacher-student, curator-visitor), reliable communication, and shared outcomes. Professionals (G3) stressed workflow stability and provenance traceability, educators (G1) emphasised guided control of group pace, while artists (G2) sought flexible modes of co-creation. To capture these insights in a transparent and actionable way, the table below maps each high-level goal (WHY) to corresponding user tasks, functions, indicative metrics, and their alignment with the relevant work packages. Implementation feasibility will depend on WP2's prioritisation and technical constraints; not all user-identified needs can be realised within IMPULSE's scope, budget, or timeline.

10 Gap Analysis per Experience Goal

This chapter integrates insights from the literature review (Section 5.5), findings from the user research presented in Chapter 8, and relevant conclusions from research to produce a structured gap analysis for each experience goal.

The purpose is to provide a transparent account of:

- what is currently established and available in the field of immersive cultural heritage (state of the art);
- where significant limitations or barriers remain (identified gaps);
- how IMPULSE seeks to address these gaps within its defined scope, resources, and methodological framework (project implications).

The identification of potential strategies to mitigate the observed gaps in the IMPULSE platform, including the definition of feasible functionalities, falls under the responsibility of WP2. These decisions will be taken in line with the project's technical capacities, interoperability objectives, and resource constraints.

By systematically aligning the state of the art and the identified gaps with the experiential (high-level) goals outlined in Section 5.6, the analysis avoids over-promising advanced functionalities while demonstrating how IMPULSE contributes to the broader European research and innovation agenda for digital cultural heritage. Each subsection therefore provides a concise overview of the current landscape, specifies remaining challenges, and delineates the realistic contribution of IMPULSE within its operational boundaries.

10.1 Embodied experience of cultural heritage environments and contexts.

Immersive technologies such as VR and AR have been increasingly applied to the reconstruction and exploration of cultural heritage (CH) environments. Examples include virtual tours of archaeological sites, museum-based VR installations, and GIS-linked 3D models used in research and conservation. These approaches have shown considerable potential for enhancing spatial understanding, supporting cultural interpretation, and stimulating public interest. In particular, immersive reconstructions are valued for their capacity to situate objects in their historical or architectural context, thereby improving comprehension and recall.

Observed gaps

Despite these advances, several challenges remain. First, most high-fidelity applications rely on costly professional tools (e.g. GIS systems, CAD/BIM-based reconstructions)

that require specialist expertise and are not widely accessible to educators, students, or creative practitioners. Second, immersive reconstructions often prioritise visual fidelity over narrative depth or user co-creation, leaving little room for exploratory or participatory engagement. Third, there is a lack of lightweight, interoperable solutions that can bridge the gap between academic/professional-grade modelling and accessible, narrative-driven experiences for broader audiences.

Relevance for IMPULSE framework

IMPULSE does not aim to deliver professional-grade GIS or architectural modelling. Instead, it supports **exploratory and narrative-driven engagement** with cultural heritage environments. The platform provides only the essential features required for spatial orientation (e.g. basic navigation, multi-user tours, contextual annotations), enabling users to gain a **basic sense of spatial and historical context**. This approach is consistent with both the project's scope and resource constraints, while remaining aligned with the high-level experience goal of fostering cultural understanding. Advanced integration with GIS or CAD datasets is recognised as a valuable future direction but remains outside the current scope of IMPULSE.

10.2 Creating memorable and trustworthy encounters.

Immersive media are widely reported to enhance engagement, attention, and short-term recall through presence, interactivity, and multimodal cues (e.g., audio narration, spatial sound, close-up inspection, pacing). Narrative structuring story arcs, guided tours, and situated vignettes helps users connect artefacts with time, place, and actors, which in turn supports meaning-making and memory encoding. In museum and HE settings, educators frequently combine immersive scenes with prompts, discussion, or quizzes to consolidate learning. On the "historical soundness" axis, good practice emphasises source transparency (metadata, references), paradata (how reconstructions were made), and clear signalling of uncertainty (what is known, inferred, or speculative).

Observed gaps

Despite promising findings, several limitations persist:

1) memorability evidence is often short-term (immediate post-test), with little longitudinal evaluation of durable learning or transfer.
2) cognitive overload and the novelty effect can reduce knowledge retention if stories are dense, interaction is unclear, or pacing is not scaffolded.
3) historical credibility is uneven: many immersive experiences lack explicit sources, paradata, or uncertainty cues, leading to false confidence or anachronistic readings.

4) authoring tools for educators/curators remain limited: few lightweight means to layer facts, commentary, and reflective prompts without technical support.
5) evaluation practices are inconsistent: memorability and credibility are not routinely operationalised as measurable outcomes in deployment contexts.

Relevance for IMPULSE framework

Within scope and resources, IMPULSE targets memorability and credibility as experience intentions, not as promises of scholarly adjudication or exhaustive historiography. Concretely, the platform will:

- enable layered narratives (factual layer; educator/curator commentary; creative layer) with user-controlled pacing (pause/rewind/skip) to reduce overload;
- surface metadata and paradata on demand, and support uncertainty signalling (what is established vs. inferred);
- provide lightweight recall/quiz hooks and prompting templates so educators can consolidate learning without external tools;
- prioritise transparent sourcing and attribution at object and scene level, while avoiding claims to professional-grade scholarly reconstruction.

10.3 Inspection and manipulation of CH objects.

3D digitisation of cultural heritage objects has expanded rapidly, with museums and repositories offering high-quality scans for conservation, research, and public engagement. Advanced platforms and professional tools (e.g. CAD, photogrammetry software, digital twin systems) allow precise measurement, high-fidelity rendering, and simulation of material properties. In parallel, lighter-weight viewers (Sketchfab, Smithsonian 3D, Europeana's 3D pilots) have demonstrated the appeal of web-accessible interaction, like zooming, rotating, and inspecting models though usually in limited, non-collaborative modes. For scholars, conservators, or architects, these tools support detailed analysis; for general audiences, they support exploration and appreciation.

Observed gaps

1) **Accessibility gap**: professional-grade inspection tools require specialist skills, costly hardware, and are often closed-source.
2) **Pedagogical gap**: existing viewers rarely include scaffolding features such as contextual annotations, guided comparison, or didactic templates.
3) **Collaborative gap**: most 3D viewers are single-user and do not support co-inspection or discussion in real time.

4) **Integration gap**: metadata and paradata (sources, methods, provenance) are often detached from the 3D interaction, weakening trust and transparency.
5) **Stability gap**: as observed in the Leuven workshop, even lightweight import of large files or unsupported formats can destabilise performance, limiting usability in live educational or creative settings.

Relevance for IMPULSE framework

IMPULSE does not attempt to replicate specialist CAD or conservation environments. Instead, it focuses on **basic, intuitive manipulation of CH objects** in support of exploratory learning, creativity, and cultural engagement. Within scope, the platform will:

- provide **core manipulation tools** (zoom, rotate, move, annotate, compare) optimised for non-expert use;
- enable **on-demand metadata and paradata overlays**, allowing users to link object handling with source transparency;
- support **guided comparison modes** (e.g. side-by-side inspection, narrative prompts) for educators and curators;
- integrate **role-based multi-user inspection** (teacher/student, curator/visitor, artist/collaborator) to enable co-exploration and dialogue.

10.4 Narrative structuring and storytelling.

Storytelling is increasingly recognised as a central affordance of immersive cultural heritage technologies. VR and MUVE platforms have been used to deliver linear guided tours, branching storylines, and multi-layered narrative experiences, allowing users to connect artefacts and environments through meaningful sequences. Narrative immersion is linked to enhanced emotional engagement, cultural empathy, and memory retention. In the CH sector, pioneering projects (e.g., museum-based VR installations, experimental AR storytelling) have shown that curators and educators can employ digital narratives to situate heritage within broader social, historical, or artistic contexts. Academic research highlights the promise of interactive narratives and co-created storytelling, where users are not only consumers but also contributors to cultural narratives.

Observed gaps

1) **Authoring barrier**: most narrative design in VR still requires technical expertise; non-programmers (educators, curators, artists) lack accessible authoring tools.

2) **Pedagogical under-use**: few platforms provide ready-made templates for didactic storytelling (e.g. lesson plans, guided reflection tasks).
3) **Evaluation deficit**: impact of immersive storytelling on empathy, cultural literacy, and interpretation remains under-researched, especially in authentic classroom or exhibition contexts.
4) **Co-creation gap**: while participatory design is discussed in the literature, few systems allow users to **author, annotate, or remix narratives collaboratively**.
5) **Sustainability challenge**: narrative prototypes are often siloed experiments, with limited interoperability and re-use across platforms or repositories.

Relevance for IMPULSE framework

IMPULSE positions narrative not as a fixed "curatorial product" but as a dynamic layer of engagement across education, creativity, and professional practice. Within scope, the platform will:

- provide **lightweight authoring tools** for non-technical users, supporting branching, linear, or layered storytelling;
- integrate **pedagogical scaffolds**, such as didactic templates, quizzes, and reflective prompts, that can be reused by educators;
- enable **collaborative storytelling** within MUVE contexts, allowing artists, curators, and students to co-construct or remix narratives in shared sessions;
- ensure **metadata and paradata integration**, so that narratives remain transparent about sources, interpretive choices, and speculative elements.

10.5 Social co-presence and co-creation (MUVE).

Multi-user virtual environments (MUVEs) and immersive communication (IMCo) platforms have a long trajectory, from early experiments such as *Second Life* to more recent tools like Mozilla Hubs, AltspaceVR, or EngageVR. These environments demonstrate that social co-presence, the feeling of "being there together" can substantially increase user engagement, foster collaboration, and create shared meaning-making opportunities. In the cultural heritage sector, pilot projects have shown the potential of collaborative VR tours, multi-user exhibition walkthroughs, and online participatory reconstructions. Research underlines that role differentiation (e.g. teacher/student, curator/visitor) enhances both learning outcomes and professional workflows.

Observed gaps

1) **Limited adaptation for CH**: mainstream MUVE platforms rarely provide tools tailored to cultural heritage, such as object provenance, layered narratives, or curatorial annotation.
2) **Usability barriers**: many multi-user platforms require technical set-up, log-in hurdles, or high bandwidth, which limits accessibility for schools, small museums, and remote communities.
3) **Pedagogical and curatorial gap**: few solutions support structured educational roles or curated pathways within multi-user sessions.
4) **Moderation and inclusivity challenges**: persistent issues with role management, safeguarding, and language accessibility hinder wider adoption.
5) **Integration gap**: synchronous co-presence is often disconnected from asynchronous collaboration (e.g. session recording, annotation persistence).

Relevance for IMPULSE framework

IMPULSE recognises social co-presence as a **core experiential goal** but addresses it within realistic boundaries. The platform will:

- support **basic synchronous co-presence** (shared exploration, avatar presence, role assignment) for education, artistic co-creation, and professional curation;
- provide **role-based interaction modes** (e.g. guide/follower, curator/visitor, teacher/student) that map onto real-world CH practices;
- include **lightweight moderation tools** (session control, permissions) to ensure safe and inclusive collaboration;
- enable **session recording and annotation persistence**, bridging synchronous and asynchronous engagement.

10.6 Accessibility and inclusivity

Accessibility and inclusivity are recognised as priorities in digital cultural heritage, reinforced by the **European Accessibility Act** and WCAG standards. In web environments, accessibility measures such as captions, screen-reader support, and alternative navigation are increasingly common. However, immersive VR and MUVE contexts lag behind: many platforms lack systematic accessibility design, and inclusive practices are rarely mainstreamed. Research emphasises the risks of **digital divides** both technological (hardware costs, bandwidth needs) and social (language barriers, cultural

representation). Pilot projects have explored adaptive interfaces, haptic feedback, and multimodal interaction, but these remain fragmented and rarely scaled.

Observed gaps

1) **Hardware barriers**: high costs and technical demands restrict access for schools, small cultural institutions, and underrepresented communities.
2) **Design gaps**: most VR experiences neglect basic accessibility features (captions, audio description, simplified navigation).
3) **Inclusivity deficit**: representation of diverse cultures, languages, and perspectives remains limited; immersive content often reflects dominant narratives.
4) **Policy-practice gap**: while EU guidelines stress accessibility, implementation in immersive CH projects is inconsistent.
5) **User competence gap**: limited digital literacy among some groups (noted in G1 surveys and interviews) exacerbates exclusion risks.

Relevance for IMPULSE framework

IMPULSE cannot remove systemic hardware barriers but commits to **designing inclusively within scope**. The platform will:

- ensure basic accessibility features (captions, audio narration, simplified navigation modes, scalable text sizes);
- provide low-threshold onboarding (tutorials, role-based guidance) to support users with limited digital competences;
- adopt inclusive content strategies, encouraging diversity of narratives, user-contributed perspectives, and multilingual support where feasible;
- design for progressive enhancement: core experiences run on standard VR-ready PCs, while optional extensions can exploit higher-end equipment.

10.7 Sustainability and re-use of digital CH assets

Sustainability and re-use are central to European policy frameworks for digital cultural heritage, particularly in relation to the **European Collaborative Cloud for Cultural Heritage (ECCCH)**, Europeana, and FAIR principles (Findable, Accessible, Interoperable, Reusable). Large-scale repositories and research infrastructures increasingly provide 3D assets, metadata standards, and APIs, which form the backbone of sustainable cultural data ecosystems. However, integration with immersive platforms (VR/MUVE) remains limited. Many VR applications are built as **one-off prototypes** or exhibition pilots, lacking mechanisms for long-term maintenance, interoperability, or community-driven adaptation. As a result, valuable content often becomes siloed or technically obsolete.

Observed gaps

1) **Interoperability gap**: VR and MUVE applications frequently rely on bespoke formats or closed environments, hindering asset exchange with repositories like Europeana or ECCCH.
2) **Longevity gap**: many immersive prototypes are not maintained beyond project funding, leading to technological obsolescence and lost value.
3) **Scalability gap**: reusable frameworks for multi-user collaboration, metadata integration, and narrative layering are rare.
4) **Sustainability tension**: high-energy demands of immersive rendering raise questions about environmental impact, while lightweight alternatives are under-researched.
5) **Community re-use gap**: cultural and creative industries (CCI), educators, and artists lack accessible pathways to re-use VR content for new purposes.

Relevance for IMPULSE framework

IMPULSE addresses sustainability and re-use as enablers, not as end-to-end infrastructure delivery. Within scope, the platform will:

- adopt **interoperability standards** (e.g. IIIF for images, linked data for metadata, open 3D formats where feasible);
- design for **modularity**, so that narrative scenarios, user annotations, and object sets can be re-used in future contexts;
- provide **export functions** (e.g. annotated scenes, narrative scripts) that can be archived or integrated with external repositories;
- align recommendations with **ECCCH priorities**, highlighting where IMPULSE outputs could be incorporated into wider European infrastructures;
- promote **energy-conscious design choices** (e.g. lightweight rendering, minimising duplication of large files).

11 Recommendations (Focused)

The recommendations presented in this chapter synthesise the outcomes of the user research (Chapter 8), the functional requirements (Chapter 9). In contrast to the more detailed analyses provided earlier, these recommendations are deliberately concise and focused, outlining the strategic priorities that should guide the subsequent stages of IMPULSE. They are grouped into three thematic areas: (i) general design principles applicable across all work packages, (ii) narrative and interaction design guidance, and (iii) cross-WP priorities with a roadmap of immediate and subsequent actions.

General Design Recommendations

User research confirms that immersive cultural heritage platforms must remain accessible, interoperable, and narratively engaging. Accordingly, IMPULSE should prioritise:

simplicity of use, ensuring low entry thresholds for non-expert users;
inclusivity by design, addressing diverse accessibility needs;
compliance with interoperability standards, enabling data exchange and reuse.

These transversal principles apply across all work packages: WP2 (prototype development), WP3 (standards and interoperability), WP4 (validation and IPR), and WP5 (dissemination and community engagement).

Narrative and Interaction Design

Narrative integration should balance structured learning objectives with open-ended creative exploration. Interaction design should emphasise clarity, memorability, and ease of manipulation, enabling users to navigate immersive environments and engage meaningfully with cultural heritage objects. Multi-layered narrative structures should support role-based participation (e.g. teacher/student, curator/visitor, artist/collaborator), fostering co-presence, contextual understanding, and reflective interpretation while maintaining a lightweight, intuitive interface.

Cross-WP Priorities and Roadmap

Drawing on convergent evidence from workshops, surveys, and interviews, three cross-WP priorities have been identified, aligned with the core objectives of each work package:

Stable and precise 3D object manipulation – essential for both educational (G1) and professional (G3) use cases (WP2/WP3).

- **Multi-user co-presence with guided tour functionality** – supporting collaborative learning, co-creation, and community building (WP2/WP3/WP5).
- **Integration of metadata and provenance information within immersive scenes** – ensuring interpretive depth, traceability, and alignment with European CH standards (WP2/WP3/WP4).

Subsequent development cycles may explore extended functionality such as advanced authoring tools, enhanced avatar customisation, or comparative testing. These directions are framed as **long-term recommendations**, not immediate priorities.

The roadmap therefore follows a **"core-first" principle**: ensuring that the foundational functionality of IMPULSE remains stable, inclusive, and evidence-driven before introducing optional or exploratory features.

12 Conclusion

Purpose and contribution.

This deliverable (D1.2) consolidates the first full cycle of user evidence for IMPULSE and transforms it into a coherent bridge from experience goals (WHY) to functional requirements (WHAT/HOW) and an evaluation strategy (EVIDENCE). Building on mixed-methods research (workshops, surveys, interviews), it clarifies the high-level experiential intentions of the project and distils them into feasible, low-level goals across three functional domains: *Authoring, Experiencing*, and *Community* (MUVE/IMCo). In doing so, D1.2 addresses the reviewers' key concern regarding the conflation of analysis levels and the missing "WHY", providing instead a structured theory of change supported by measurable indicators. Furthermore, D1.2 provides a user-centred evidence base and a set of recommendations that inform both the immediate implementation of IMPULSE and the longer-term development of immersive cultural heritage practices. It does **not** impose new development obligations beyond the Grant Agreement but offers a rational framework for evidence-based prioritisation across WP2-WP5.

What the user evidence shows.

Across all user groups (G1-G3), consistent patterns emerged:

- **G1 (education)** emphasised narrative scaffolding, memorability, and spatial orientation;
- **G2 (artistic research)** valued creative freedom, lightweight authoring, and opportunities for co-creation;
- **G3 (professional practice)** prioritised system stability, transparent metadata/paradata, and workflow reusability.

Common barriers included navigation and onboarding hurdles, limited annotation visibility, connectivity fragility in multi-user sessions, and constraints on large assets. These findings directly informed the operational (low-level) goals and the functional requirements presented in Chapter 9.

Responding to scope and feasibility (WP2 alignment).

To preserve realism, all high-level goals are articulated as **intentions for user experience**, not as commitments to professional-grade toolsets. For example, "Understanding CH environments and context" refers to exploratory, narrative-driven engagement rather than GIS/BIM-level simulation. Similarly, "Precise manipulation" implies intuitive inspection and comparison rather than CAD-class modelling. This ensures alignment with WP2 feasibility while maintaining user relevance and policy coherence. The resulting Top-3 cross-WP priorities are pragmatic and sequenced:

stable, precise 3D object manipulation;
multi-user co-presence with guided tour capability;
in-scene metadata and paradata for credibility and re-use.

Other features (e.g., richer avatar expressiveness, advanced authoring automations) are explicitly positioned as *next-stage enhancements*.

Limitations and risks.

As an early proof-of-concept cycle, results should be interpreted with caution. The Leuven prototype constrained testing (limited 3D assets, no teleportation, no persistent shared annotations, sensitivity to large files), and participant samples reflect early adopters rather than full European representativeness. Remaining risks include performance at scale, network reliability, access inequities, and interoperability overheads. Mitigation measures are integrated into the roadmap: progressive enhancement, desktop fallbacks, guided onboarding, role-based session control, template-based authoring, standards-aware export packages, and privacy-by-design procedures (WP4).

Closing statement.

D1.2 consolidates the first cycle of user research, offering an integrated view of how audiences engage with immersive cultural heritage. The report translates empirical findings into evidence-based insights that support the ongoing development of IMPULSE. Rather than prescribing solutions, it provides recommendations that may guide further work on MUVE environments and digital heritage. D1.2 thus stands as a key analytical milestone, grounding the project in user evidence and contributing to inclusive, sustainable, and interoperable cultural heritage practices.

References

Agulló, B., Matamala, A., & Orero, P. (2019). Making interaction with virtual reality accessible: rendering and guiding methods for subtitles. *AI EDAM*, 33(S4), 416-428. https://doi.org/10.1017/S0890060419000362

Alsuwaidi, A., & Almazrooei, A. (2025). *Revolutionizing cultural heritage engagement through the metaverse: A study on virtual interactivity and perception*. In Springer Proceedings in Business and Economics. Springer. https://doi.org/10.1007/978-3-031-77975-6_12

Bekele, M. K., & Champion, E. M. (2019). A comparison of immersive realities and interaction methods: Cultural learning in virtual heritage. *Frontiers in Robotics and AI, 6*, 91. https://doi.org/10.3389/frobt.2019.00091

Besoain, F., González-Ortega, J., & Gallardo, I. (2022). An evaluation of the effects of a virtual museum on users' attitudes towards cultural heritage. *Applied Sciences, 12*(3), 1341. https://doi.org/10.3390/app12031341

Biswas, N., Mukherjee, A., & Bhattacharya, S. (2024). "Are you feeling sick?" A systematic literature review of cybersickness in virtual reality. *ACM Computing Surveys, 56*(11), 1-38.

Boboc, R. G., Voinea, G. D., & Butnariu, S. (2024). Investigating tourist acceptance of a VR multisensory system in a public weapons exhibition. In L. T. De Paolis, P. Arpaia, & M. Sacco (Eds.), *Extended Reality. XR Salento 2024* (Lecture Notes in Computer Science, Vol. 15029). Springer. https://doi.org/10.1007/978-3-031-71710-9_19

Chang, E., Kim, H. T., & Yoo, B. (2020). *Virtual Reality Sickness: A Review of Causes and Measurements*. International Journal of Human-Computer Interaction, 36(17), 1658-1682. https://doi.org/10.1080/10447318.2020.1778351

Dick, E. (2021, June 1). *Risks and Challenges for Inclusive and Equitable Immersive Experiences*. Information Technology & Innovation Foundation. Retrieved from https://itif.org/publications/2021/06/01/risks-and-challenges-inclusive-and-equitable-immersive-experiences/

Dreksler, B., & Bacha, K. (2025). Can collaboration in multiuser immersive virtual reality streamline the design process? *Journal of Digital Landscape Architecture, 10*, 45-52. https://doi.org/10.14627/537754005

Giaretta, A. (2025). Security and privacy in virtual reality: a literature survey. *Virtual Reality* 29, 10. https://doi.org/10.1007/s10055-024-01079-9

IMPULSE Project proposal (2023). IMPULSE, IMmersive digitisation: uPcycling cULtural heritage towards new reviving StratEgies. PROPOSAL_101132704-IMPULSE HORIZON-CL2-2023-HERITAGE-01-PART_B_Section_1.pdf (Available: https://ujchmura.sharepoint.com/:b:/r/teams/impulsegeneral_group/Shared%20Documents/General/Proposal/Grant%20Agreement%20-%20GAP-101132704.pdf?csf=1&web=1&e=34LXgI).

Innocente, C., Ulrich, L., Moos, S., & Vezzetti E. (2023). A framework study on the use of immersive XR in cultural heritage. *Journal of Cultural Heritage*. https://doi.org/10.1016/j.culher.2023.06.001

ISO = International Organization for Standardization. (2019). ISO 9241-210:2019 - Ergonomics of human-system interaction -Human-centred design for interactive systems. https://www.iso.org/standard/77520.html.

Komianos, V., Tsipis, A., & Kontopanagou, K. (2024). Introducing digitized cultural heritage to wider audiences: Evaluating virtual museums through design and user requirements. *Technologies, 12*(10), 196. https://doi.org/10.3390/technologies12100196

Krakowska, M., Zych, M., Deja, M. (2024). D1.1 -Methodological framework and user groups definition (Version 6.0). Horizon Europe Project IMPULSE (GAP-101132704). Jagiellonian University.

Available:IMPULhttps://ujchmura.sharepoint.com/:b:/r/teams/impulsewp1ex-story_group/Shared%20Documents/General/Task%201.1_UserResearch/1.1.2Methodology%26ResearchTechniques%20creation%20(M3-6)/DELIVERABLE1/IMPULSE%20D1.1_version%206.0_30.07.2024.pdf?csf=1&web=1&e=p214cw).

Miller, M. R., Herrera, F., Jun, H., Landay, J. A., & Bailenson, J. N. (2020). Personal identifiability of user tracking data during observation of 360-degree VR video. *Scientific reports*, *10*(1), 17404. https://doi.org/10.1038/s41598-020-74486-y

Mortara, M., Catalano, C. E., Bellotti, F., Fiucci, G., Houry-Panchetti, M., & Petridis, P. (2014). Learning cultural heritage by serious games. Journal of Cultural Heritage, 15(3), 318-325. https://doi.org/10.1016/j.culher.2013.04.004

Msweli, N. T., & Phahlane, M. (2025). *Health-Related Issues of Immersive Technologies: A Systematic Literature Review*. Informatics, 12(2), 47.

Petousi, D., Katifori, A., Servi, K., & Ioannidis, Y. (2022). Interactive digital storytelling in cultural heritage: The transformative role of agency. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Bioinformatics)* (pp. 45-58). Springer. https://doi.org/10.1007/978-3-031-22298-6_3

Pujol, L., & Champion, E. (2012). Evaluating presence in cultural heritage projects. International Journal of Heritage Studies, 18(1), 83-102. https://doi.org/10.1080/13527258.2011.577796

Rodriguez-Garcia, B., Guillen-Sanz, H., Checa, D. *et al.* A systematic review of virtual 3D reconstructions of Cultural Heritage in immersive Virtual Reality. *Multimed Tools Appl* 83, 89743-89793 (2024). https://doi.org/10.1007/s11042-024-18700-3

Sangamuang, S., Wongwan, N., Intawong, K., & Puritat, K. (2025). Gamification in virtual reality museums: Effects on hedonic and eudaimonic experiences in cultural heritage learning. *Informatics, 12*(1), 15. https://doi.org/10.3390/informatics12010027

Shehade, M., & Stylianou-Lambert, T. (2020). Virtual reality in museums: Exploring the experiences of museum professionals. *Applied Sciences, 10*(12), 4031. https://doi.org/10.3390/app10114031

Shikhri, R., Poretski, L., & Lanir, J. (2023). Analyzing behavior and user experience in online museum virtual tours. *arXiv*. https://arxiv.org/abs/2310.11176

Spadoni, E., Carulli, M., Ferrise, F., & Bordegoni, M. (2023). Impact of multisensory XR technologies on museum exhibition visits. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Bioinformatics)* (pp. 212-223). Springer. https://doi.org/10.1007/978-3-031-35897-5_9

Yolthasart, S., Intawong, K., Thongthip, P., & Puritat, K. (2024). The game of heritage: Enhancing virtual museum visits through gamification for tourists. *TEM Journal, 13*(2), 453-462. https://doi.org/10.18421/TEM134-70

Yu, J., Wang, Z., Cao, Y., Cui, H., & Zeng, W. (2025). Centennial drama reimagined: An immersive experience of intangible cultural heritage through contextual

storytelling in virtual reality. Journal on Computing and Cultural Heritage, 18(1), Article 11, 1-22. https://doi.org/10.1145/3705613

Zhang, Z.-H., & Huang, H.-C. (2025). Enhancing Sustainable Tourism Through Virtual Reality: The Role of Collectable Experiences in Well-Being and Meaning in Life. *Sustainability*, *17*(13), 5809. https://doi.org/10.3390/su17135809

13 Annexes

13.1 Questionnaire IMPULSE VR Platform Testing prepared for Leuven workshop.

IMPULSE VR Platform testing

The purpose of this survey is to identify the respondent's opinions regarding the scope and quality of functionalities available in the platform and to explore the respondents' opinions on the expected scope of functionalities in the final version of the platform. The survey is anonymous, and you can stop answering at any time. Please note that, because it is anonymous, we cannot delete or edit responses once the survey is complete. The survey should take approximately 10 minutes to complete. There are no right or wrong answers -we want to hear your honest feedback. Thank you for your time and for sharing your knowledge and experience. Please be aware that during the survey, there is a risk of experiencing VR sickness. Symptoms may include dizziness, nausea, headaches, vomiting, and general discomfort. The survey can be stopped at any moment upon the participant's request. However, if you are concerned about the potential for VR sickness, we encourage you to carefully consider your participation in the study.This survey is part of the IMPULSE project. If you have any questions or concerns, please feel free to contact us via https://euimpulse.eu/contact/

* Required

1. Do you agree to participate in the survey "VR Platform testing" carried out as part of the IMPULSE project? *

   Yes

   No

2. How would you assess the platform in relation to the following pair of attributes? *

unpleasantpleasant

3. How would you assess the platform in relation to the following pair of attributes? *

   brings me closer to people separates me from people

4. How would you assess the platform in relation to the following pair of attributes? *

simple complicated

5. How would you assess the platform in relation to the following pair of attributes? *

unimaginativecreative

6. How would you assess the platform in relation to the following pair of attributes? *

motivatingdiscouraging

7. How would you assess the platform in relation to the following pair of attributes? *

ugly attractive

8. Have you experienced any difficulties importing 2D content while using the platform? If so, which ones? (You may select more than one option.) *
Problems with the supported file format (e.g. the platform does not recognise .svg, .png, etc. files)

Slow loading of the content

Failure to load the content due to too large file size

Technical errors (e.g. platform crashed during import)

Incorrectly imported content (e.g. missing elements, distortions)

No, I have not experienced any difficulties

Inne

9. Have you had any difficulties moving content within the platform environment? If so, which ones? (You may select more than one option.) *
Problems with the precision of the content's movement

Content 'jumped' or changed position not according to my expectations

Lack of clear guidance or visual cues (e.g. no grid display, on-screen cues showing the model's current position or possible directions of movement)

Controller issues (e.g. difficulty using VR goggles or keyboard/mouse)

No, I have not experienced any difficulties

Inne

10. Have you had any difficulties changing the size of the content on the platform? If so, which ones? (You may select more than one option.) *
Lack of precision when changing size (e.g. the content changed size in jumps instead of smoothly)

Limited ways to change scale (e.g. no way to zoom in/out to the right size)

Unclear instructions on how to use features (e.g. no explanation of which gestures or buttons to use to change size; no visual indication of the model's current size)

Technical problems (e.g. platform freezes)

No, I have not experienced any difficulties

Inne

11. Did you have any difficulties moving around the environment? If so, what were they? (You may select more than one option.) *
Problems with steering (e.g. no clear steering instructions)

Poor fluidity of movement (e.g. delays or lag in movement)

Difficulty navigating with respect to objects (e.g. walking into objects, collisions with objects)

Restricted field of vision or difficulty orienting in space

Symptoms of VR sickness (e.g. dizziness, nausea, disorientation)

Controller-related technical problems (e.g. lack of control precision)

No, I did not experience any difficulties

Inne

12. Did you find it easy to use the interface (e.g. VR goggles, controllers, keyboard + mouse) to interact with the platform? *

Very difficultVery easy

13. Please describe any specific problems you faced when using the interface (optional)
14. While using an immersive (VR) environment, have you encountered any difficulties related to any of the following aspects? (You may select more than one option.) *
Difficulties initiating communication with other users.

Unclear or confusing instructions on how to navigate or use the environment.

Uncertainty about what to do at a given moment (e.g., how to complete a task or continue interacting).

Trouble locating specific functions (e.g., what to click, touch, or how to activate certain features).

Challenges navigating through the virtual environment (e.g., moving around, changing perspective).

Emotional or social difficulties (e.g., stress, uncertainty, feeling intimidated when interacting with others).

Difficulty concentrating or understanding the information being presented.

Technical issues that hinder communication (e.g., delays, malfunctioning voice or text interfaces).

No, I did not experience any difficulties

Inne

15. What additional functionalities would you like to see in the final version of the platform? Select up to 3 options that are most important to you. * Wybierz co najwyżej 3 opcje.

Ability to edit the VR environment (e.g. change backgrounds, add/remove elements of the environment)

Ability to personalise your avatar (e.g. choice of appearance, e.g. skin colour, hair, clothes; ability to add accessories such as glasses or hats; choice of gesture animation)

Ability to change the way you move (walking, flying, teleportation -depending on user preference)

Enhanced communication options (e.g. text chat, video chat, indications of emotional reactions such as emojis, nonverbal cues by virtual characters, etc.)

Inne

16. Do you have any additional comments on the use of the platform that you would like to share with us?
17. How did you experience the platform? * Using VR goggles

Using a computer screen (VR desktop)

18. How would you describe your prior experience with VR before participating in this study? *

I had no prior experience with VR (Non-user)

I had limited experience with VR (Beginner)

I use VR occasionally (Intermediate)

I am an experienced VR user (Expert)

13.2 Questionnaire IMPULSE -Needs and expectations of VR users.

IMPULSE -Needs and expectations of VR users

The purpose of this survey is to explore the needs, expectations and experiences of users and potential users of VR. The survey is anonymous. It will take approximately 10-12 minutes to complete. There are no right or wrong answers -we are interested in your personal experience and opinions. Please respond to all questions. Thank you for your participation! Your answers are extremely valuable to us.

This survey is part of the IMPULSE -IMmersive digitisation: uPcycling cULtural heritage towards new reviving StratEgies EU Funded Project: 101132704. If you have any questions or concerns, please contact us at https://euimpulse.eu/contact/.If in the future you would like to take part in an interview or test our VR platform, we encourage you to contact us via the form available on the website. You can also join IMCo, an open community of people involved in the development of immersive

technologies. It's a space to share knowledge, experience and ideas. You can find more information about IMCo here: https://euimpulse.eu/introducing-imco-the-impulse-community-ofpractice/

* Required

1. Do you agree to participate in the 'IMPULSE -VR user needs and expectations' survey conducted by the IMPULSE project? *

Yes

No

Experience with VR

1. Have you ever used VR? *

Yes, on a regular basis

Yes, but occasionally

Yes, once (e.g. during a class or an exhibition)

No, but I would like to

No and I am not interested

2. How often do you use VR technology? * Never

Rarely (once a year or less often)

Occasionally (several times a year)

Often (several times a month)

Very often (weekly or more often)

3. How would you rate your level of expertise in VR? *

Beginner

Intermediate

Advanced

Expert

4. What VR devices have you used? (Select all that apply) *

- Oculus Rift/S
- Oculus Quest/Quest 2
- HTC Vive
- Valve Index
- PlayStation V
- I do not know
- Inne

5. What VR platforms have you used most often? (You can choose more than one answer). *

- Spatial
- VR Chat
- Meta Horizon
- Decentraland
- Open Simulator
- Roblox
- Sandbox
- I am using Unity products
- I am using WebGL products
- I do not use
- I do not know
- Inne

6. What are your main reasons for using VR? (You can choose more than one answer). *

- Entertainment (games -including desktop games, films)
- Education and training
- Creativity and art
- Cooperation and teamwork
- Exploring new technology

Inne

7. What difficulties have you encountered when using VR? (You can choose more than one answer). *

Technical issues

High cost of equipment

Physical discomfort (e.g. dizziness, nausea)

Lack of knowledge about VR

Limited social interaction

I have not encountered any difficulties

Inne

8. Briefly describe what you associate your experiences in the VR environment so far with. Name them, give associations. *

Social interactions in VR

10. "Please rate the following statements on a scale from 1 to 7: (1 = strongly disagree, 7 = strongly agree)" *

1 -strongly 4 -hard to 7 -strongly disagree 2 3 say 5 6 agree

I feel like a part of the group in the virtual world.

During interactions in VR, I pay attention to other users.

In VR, I can easily understand other users' intentions and emotions.

Communication in VR feels as natural to me as in the real world.

Collaboration in VR is more engaging than in traditional applications.

Expectations toward VR

11. Which VR features are/would be the most important to you? (Select up to 3) *

Wybierz co najwyżej 3 opcje.

World realism

High-quality social interactions

Intuitive controls and ease of use

Ability to create and be creative

Access to educational and professional content

I don't know / Hard to say

Inne

Interacting with VR elements

(e.g., digital objects, virtual items, parts of the virtual environment, virtual exhibits, 3D objects, visualizations, etc.)

12. Please rate the following statements on a scale from 1 to 7:(1 = strongly disagree, 7 = strongly agree) *

	1 -strongly disagree	2	3	4 -hard to say	5	6	7 - strongly agree
Interaction with virtual elements is intuitive for me.							
Virtual objects help me feel more immersed in the VR world.							
Objects in VR should be more realistic.							

13. Have you previously interacted with digital cultural heritage objects (e.g., digitized books, scanned paintings, 3D models, scans of sculptures, monuments, etc.)? *

Yes

No

14. Please describe your experience with digital cultural heritage objects. *

Barriers and Expectations

15. Why don’t you use VR? (You may select more than one answer.)" *

I don't have the necessary equipment.

VR is too expensive.

I don't know how to get started.

I don't see the value in it.

I'm not interested in VR.

I haven't had the opportunity to try it.

Inne

16. What could convince you to start using VR? (You may select more than one answer.) *

Cheaper and easier access

Improved graphics and immersion quality

More educational or professional content

Easier to use

Inne

Affiliation

17. Status at university * Student

(undergraduate)

Student (Master's degree)

PhD student

Academic teacher

Not applicable

13.3 Interview Guide.

Thanks for your participation in this interview.

Before I start asking questions, I wanted to inform you that the interview will be recorded and then transcribed. The transcriptions will be sent to you for confirmation. You can remove any information that you do not want to be part of the transcriptions. The transcriptions will be anonymized and will be published online in an open data archive.

Do you consent to the start of the recording? (YES/NO)

13.4 Demographic Data.

Please provide the following information by marking the appropriate category:
-Age:

20-30 [ ]
31-40 [ ]
41-50 [ ]
51-60 [ ]
61 and more [ ]
I don't want to say my age [ ]

-Gender:

Male [ ]
Female [ ]
Other [ ]

-Education Level:

[ ] High School
[ ] Some College
[ ] Associate Degree
[ ] Bachelor's Degree
[ ] Master's Degree
[ ] Doctorate
[ ] Prefer not to say

-Field of studies/ [artists]Artistic specialisation: _____

13.5 Interview Questions.

Question ID	*Questions*	*Notes for interviewers*
Q1: Exposure and Awareness	How would you define *virtual reality*? Can you describe your general familiarity with Virtual Reality (VR)? Have you had any exposure to VR technologies, even if you haven't used them personally? [**artists**] How do you incorporate VR/XR technologies into your artistic practice?	**Goal**: Gauge basic awareness and indirect exposure to VR technologies. **Possible follow-up questions**: -What have you heard or seen about VR that influences your perception of it? -Where do you typically encounter information about VR? **Notes to interviewer**: -What sources of information are mentioned? -Are there any misconceptions or accurate understandings evident? **Possible follow-up questions:** -How do you integrate XR (VR, AR, or immersive experiences) in presenting your artworks? -How does the virtual environment influence your artistic choices compared to a physical studio?
Q2: Perceived Relevance	In your view, how could VR be relevant or beneficial to your studies or teaching methods?	**Goal**: Understand perceived potential uses of VR in academic contexts without prior direct experience. **Possible follow-up questions**: -Can you imagine any scenarios where VR might enhance learning or collaboration? -Are there particular subjects or activities you think would benefit from VR?

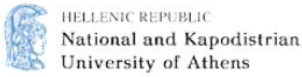
		Notes to interviewer: -What are the theoretical benefits they can think of? -Are there any specific academic disciplines they mention?
Q3: Barriers to Adoption	What are the main reasons you have not tried using VR in any form?	**Goal**: Identify barriers or lack of interest regarding VR use. **Possible follow-up questions**: -Is it a matter of access, cost, lack of interest, or something else? -Have you encountered any negative reviews or opinions that influenced your stance? **Notes for interviewer**: -What specific barriers are mentioned most frequently? -Are these barriers logistical, financial, perceptual, or cultural?
Q4: Perception of Technology	How do you generally perceive new technologies (like VR, AR, AI) in terms of accessibility and usability? How do these gaps affect your work?	**Goal**: Explore attitudes towards adopting new technologies and specific thoughts on VR's user-friendliness. **Possible follow-up questions**: -Do you feel that new technologies are designed with users like you in mind? -What could make new technologies more appealing or easier for you to try? **Notes to interviewer:** -How do they view technological advancements? -Are there any specific features or support they believe would encourage usage?

	[**artists**] How do VR and XR offer unique opportunities for artistic experimentation that other media do not?	**Goal**: The aim is to indicate the potential, aptitude, competence and perspective of the application of new VR, XR technologies in art, as well as to highlight the potential for experimentation with and in the immersive environment of artists **Possible follow-up questions:** -- Can you share an example of how using VR or XR has changed the outcome of an art project? -How does the use of XR (VR, AR or immersive experiences) impact on the perception of space and dimension in artworks? -Describe an artistic concept you could realise in VR that would be impossible in traditional or other digital formats. **Notes to interviewer:** How the artist creates immersive space, what the perception of an immersive environment means to him, how he feels this space, how it influences his work, whether it really supports experimentation and interaction with the audience?
Q5: Collaborative Potential	Considering your current methods of study or teaching, how do you think VR could impact collaboration or learning environments? How do you see its potential and challenges?	**Goal**: Elicit thoughts on the transformative potential of VR in educational settings. **Possible follow-up questions**: -What changes to learning environments do you foresee if VR were introduced? -Could VR address any current limitations in your educational experience?

	[**artists**] Does and how does interaction change in a VR environment when art is experienced by a group (of artists)? Do you think VR changes the way artists and audience perceive and interact with art? Compared to traditional viewing What unique group experiences do you believe VR and immersive installations can provide to artists that other art forms cannot?	**Notes to interviewer**: -Are there positive or negative impacts envisioned? -Do they see VR as a solution or a potential complication?

IMPULSE

IMmersive digitisation: uPcycling cULtural heritage towards new reviving StratEgies



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