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Towards a Collaborative Authoring Tool for Cultural Heritage Applications: Modelling the Development Process Between Curators and Developers

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Abstract

Both museums and virtual museums go through a curation process for creating exhibitions, with a variety of methods available. These are often collaborative, requiring both cultural heritage professionals and designers or developers working together. Mixed reality has the potential to enhance this process for the developer and client, in the form of a collaborative mixed reality authoring tool. It is important to understand the process of collaborative development of cultural heritage applications so that the authoring tool could be designed to cater for these needs.In this paper, a user study is presented that analyses the process of delivering three cultural heritage projects by an experienced development company. As a result, a model that captures project stages and collaborative aspects with the clients is created and validated, existing bottlenecks are identified and three authoring tool concepts that could improve the process are generated and discussed. The resulting tool is proposed to aid the collaboration process during the prototype and initial design stages of the development process, which will aid future research.

CCS Concepts

• ***Human-centered computing*** → ***Mixed / augmented reality;*** *Virtual reality; Collaborative and social computing systems and tools;* • ***Applied computing*** → *Arts and humanities;*

Keywords: Cultural Heritage, Mixed Reality, Authoring Tools, Virtual Museums, Cultural Heritage Application Development

1. Introduction

Museums are traditionally used to present cultural heritage to the public [PD] and requires a curation process when an exhibition is being designed. There are a variety of models proposed within the literature for how an exhibition can be created within a physical space [Dea13, Dav10, PD21]. Virtual museums would also undertake the same process but has the advantage of being less limited by the physical space of the environment [HGLS23]. For both traditional and virtual museums, cultural heritage professionals may choose to outsource the design of their interactive exhibits to third parties who are specialists in this area [MMCA14]. It is possible that mixed reality may be beneficial when designing a cultural heritage application, as both parties could collaborate together in the same space, regardless of the physical distance between them. While there is a variety of research on the role of mixed reality in digital cultural heritage [TCM20, HMAKS21] the focus is often on its use in presenting exhibitions and heritage content, not in the creation of the experiences themselves or its use in authoring tools.

In order to understand the potential role of mixed reality in the digital cultural heritage creation process, we need first understand that process and the role it might play. This paper examines the development process of three projects created by Noho[†], a producer of digital experiences for cultural heritage. Noho have collaborated with a variety of clients on a range of applications using various technologies, from desktop and touchscreen to virtual and augmented reality. The motivation for this study was to model Noho's process for developing a cultural heritage application, with the intention of designing a tool that will aid the collaboration process between curators and developers.

This paper presents our model of the digital cultural heritage creation process and three concepts for a mixed reality authoring tool. We inform our model both on an analysis of the state of the art in our field, our study with Noho, and a focus group with digital cultural heritage professionals refining and further validating it. Our model both represents an original mapping of the creation process in this space, and a design tool to help clarify the potential role of mixed reality, or other technologies, as tools for creation process at different stages within digital cultural heritage projects. Finally, the three proposed authoring tool concepts are discussed with the developers and a final concept is presented.

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2. Related Work

UNESCO categorises cultural heritage into two types: tangible and intangible [PD]. The former encompasses artefacts, monuments, buildings, or sites that have significance across various dimensions, such as symbolism, historical, artistic, aesthetic, ethnological, anthropological, scientific, and social significance contexts. The latter consists of practices, representation and knowledge skills that are acknowledged as integral components of a group or individual's cultural heritage.

UNESCO also provides a definition of digital heritage stating that digital heritage consists of a "unique resources of human knowledge and expression". It embraces a variety of resources and information created digitally or otherwise converted to digital-form from an already existing analogue resource, giving the name of "born digital" to items that lack an analogue source [UNEO03]. They attribute a wide range of materials with digital heritage, such as texts, databases, moving images, audio, software, webpages and others.

2.1. Museums and Virtual Museums

Museums are not-for-profit, permanent, and open to the public institutions which acquire, conserve, research, communicate, interpret, and exhibit both tangible and intangible heritage for study, education, and enjoyment [PD, Gar22]. Similarly, V-Must define a virtual museum as a digital entity that draws upon the characteristics of a museum to compliment, enhance, or augment the experience via personality, interactivity, and richness of content [RG15].

Virtual museums are being used as an independent mediums for the preservation and presentation of cultural heritage, as well as being used to complement physical museums [HGLS23]. In traditional museums, visitors are unable to physically interact with artefacts, as well as traditional museums being limited by the amount of space available for exhibitions [HGLS23, ZJT23]. Virtual museums are able to circumvent these problems by providing a near unlimited amount of space within the virtual experience and for allowing the users to interact with artefacts in ways that cannot be done in the real world [HGLS23]. Furthermore, virtual museums can help in preserving and presenting existing and non-existing tangible and intangible cultural heritage [MBN21, ZJT23].

2.1.1. Curation Models

Both physical and virtual museums require curated content for exhibitions. Various curation models are proposed within the literature [Dea13, PD21, Dav10].

Dean [Dea13] proposes an exhibition curation model split into four phases: the *Conceptual Phase (idea gathering)*, the *Development Phase (planning stage and production stages)*, the *Functional Phase (operational stage and terminating stages)*, and the *Assessment Phase (evaluation stage and idea gathering)*. Dean notes that exhibition curation process is rarely a linear process as well pointing out that exhibition curation can overlap between projects, with idea gathering stages happening at the start and end of the model.

Based on their own investigations into curation models, Popoli and Derda present a five stage mode [PD21] derived from analysis of various models, including Dean's model [Dea13]. They identified the key steps as being: *Initial Phase*, *Concept Phase*, *Design Phase*, *Production Phase*, and *Opening Phase*. Popoli and Derda further split these down into twenty-five substeps, as well as designating which steps are completed by the museum and design and production partners. From their interviews, it was also found that, due to the creative nature of exhibition curation, it is difficult to present the process as a series of straightforward steps.

Davies presents a non-linear model, consisting of the following stages: *Initial Idea*, *Management and Administration*, *Design and Production*, *Understanding the Audience*, *Associated Program*, and *Curatorial*. Davies emphasises that the exhibition curation process is not a linear process, whilst acknowledging that some tasks must precede others, due to the variation present during the exhibition creation process. Davies also investigated the collaborative nature of the produced model, noting that external parties are included in the exhibition process but lack involvement in management planning and curatorial stages, with a deeper level of involvement in the Initial Idea, as well as the Design and Production stages.

2.2. Mixed Reality and XR Technology

Bekele et al. [BPF*18] provide the following simple definitions for the various states of extended reality:

- *Augmented Reality (AR)* - Superimposing virtual information over the real world.
- *Augmented Virtuality (AV)* - The reverse of augmented reality, with scenes from the real world in a virtual world.
- *Virtual Reality (VR)* - Enhanced presence and interaction with purely a computer-generated environment
- *Mixed Reality (MR)* - A blend of the real world and virtual world.

A range of cultural heritage applications have made use of mixed reality. "The Ara as It Was" utilises mixed reality to enhance the visitor experiential value of the Ara Pacis monument with the goal of combining "heritage, entertainment value and heritage valorization" [TCM20]. Another example is the "MuseumEye" mixed reality application, which provides the user with a virtual tour guide who can speak to the visitor and provide visual information to the users [HMAKS21].

2.2.1. Authoring Tools

Cultural heritage applications go through an authorship process, either by commissioned developers or by cultural heritage professionals. Within the literature, a variety of cultural heritage authoring tools have been proposed [MPSV22, NP19, BAM*17].

OpenMusuem, presented by Monaco et al., is an authoring tool that utilises knowledge graphs and linked open data, in the form of a "virtual exhibition generator", to allow visitors to become a virtual museum curator [MPSV22]. Taking advantage of ELODIE (Extractor of Linked Open Data of IntErest), users can query knowledge graphs using natural language, therefore making the knowledge graph accessible, regardless of technical ability. Beyond the data selection, users are also able to include titles, descriptions, 3D models, and other multi-media URLS for the selected data. OpenMuseum also allows the user to choose from a list of potential virtual museum layouts, how the user experiences the virtual museum

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(including a VR mode), the operating system, and the light mapping quality. This data is then sent into Unity as a Json string, where the virtual museum is generated automatically and is then sent to the user via email.

Material encounterS with digital cultural heritage (meSch) [NP19] was a four year EU funded project exploring authoring tools for tangible exhibitions, using "Internet of Things" technology. Working on designing and developing an authoring platform, the authors note that cultural heritage professionals showed confidence when using it to deploy their narratives. They note a limitation with making systems too flexible, as fewer constraints can enable users to make "clumsy aggregations of contents and devices" that would require the intervention of more expert users to untangle.

Fieldscapes [BAM*17] is a virtual fieldtrip authoring tool that provides almost any IT-literate teacher with a relatively rich authoring environment to create a virtual fieldtrip using assets created by those with suitable skills to create them. A fieldscape experience can be run via smartphones headsets, tablets, PC, and using virtual reality. Fieldscape experiences also have single and multi-user modes and a lesson manager to allow students to be assigned exercises and assignments. The authors conclude that Fieldscapes "provides the closest possible experience to a physical field-trip" and is therefore able to complement and extend these, giving students the opportunity to participate in field-trips that just are not possible in a real world setting.

3. User Study

The study was designed to collect qualitative data regarding how Noho create their cultural heritage applications. To achieve this, preliminary surveys were distributed to the participants, before being invited to attend semi-structured interviews exploring each project. Once qualitative analysis was complete, the clients were invited back to attend a focus group to discuss the findings and to give their thoughts on three collaborative authoring tool concepts.

3.1. Materials

Three projects were selected for the user study, to be representative of the technology used, collaboration with external clients, and the type of cultural heritage application that was developed.

3.1.1. Seeing Ireland (SI)

Seeing Ireland (Figure 1) is an immersive recreation of the "Exposition D'Art Irlandais" art exhibition that took place in 1912 at the Galerie Barbazanges in Paris [Nohc]. For this project, Noho developed an "immersive recreation of the exhibition", an introductory video for the experience, a map of Paris with co-existing events. and a website. Additionally, Noho used their Cross-Culture Timeline ‡ system to allow for themselves and historians to enter content. The reasoning for choosing this project is due to this application being run via the web, the explicit cross-collaboration element, the project being a virtual recreation of a long since passed exhibition, and the use of their Cross-Culture Timeline system.

‡ https://crossculture.ie/

3.1.2. Beyond 2022 - Virtual Record Treasury (B22)

Beyond 2022 (Figure 1) consists of a website, a brand identity, promotional videos, and a digital reconstruction of the public records office of Ireland at the Four Courts, which was destroyed by a fire in 1922 [Noha]. The digital reconstruction also runs via the web, and Noho provides a full 3D environment for users to explore. This application ran as a VR application, a touchscreen application, and an application running within a browser. The reasoning for choosing this project is due to the multiple interaction methods available, the transition of the project between various mediums, and the collaborative factor.

3.1.3. Legends of the Lough (LOL)

Legends of the Lough (see Figure 1) is a mobile AR application centred around Lough Neagh in Ireland. QR codes are placed on signposts around the Ballyronan Marina. By scanning these codes, users are presented with virtual experiences via their phone, with information regarding the scientific and mythological origins of Lough Neagh. [Nohb]. This project was selected due to the difference from the other two investigated applications (AR application vs VR applications), anticipation of new steps in the workflow, and collaboration with a different set of clients.

3.2. Participants

There were four participants in this study. The inclusion criteria for participant recruitment were to be over the age of 18, able to give informed consent, and be affiliated with Noho. Once it was discovered that P3 was not sufficiently involved in the Seeing Ireland project, P4 was recruited to share their experience working on that project. Each was assigned a participant ID from P1 to P4.

P1 has been the Managing/Creative Director for 15 years, has contributed to 200+ projects at Noho and was interviewed for Seeing Ireland, Beyond 2022 - Virtual Record Treasury and Legends of the Lough. They primarily came up with the ideas for the projects and managed the team to achieve them. They also contributed by video editing for Seeing Ireland and Beyond 2022 - Virtual Treasury, as well as completing 3D and motion gfx tasks for Seeing Ireland. P2 was the Digital Creative Manager for 6 years, contributed to 40+ projects and was interviewed for Seeing Ireland, Beyond 2022 - Virtual Record and Legends of the Lough. They were responsible for designing the user interfaces for the projects. P3 has been a Senior Unity Developer for 6 years, has contributed to 30+ projects and was interviewed for Beyond 2022 - Virtual Record Treasury and Legends of the Lough. They were the sole developer of Legends of the Lough, as well as working on the 3D reconstruction and touch screen application for Beyond 2022 - Virtual Record Treasury. For Seeing Ireland, P3 was involved in creating content for an accompanying video and not on the interactive part of the application. P4 has been the Web/Interactive developer for 10 years, has contributed to 150+ projects and was interviewed for Seeing Ireland. They built the website, timeline, backend content management system for the timeline and paintings, as well as importing the 3D model into Babylon.js [Bab] for Seeing Ireland. They also worked on the backend content management system for Legends of the Lough and Beyond 2022 - Virtual Record Treasury, as well as converting the Unity application into Babylon.js for the latter.

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Figure 1: *Left: Seeing Ireland, Middle: Beyond 2022 - Virtual Record Treasury, Right: Legends of the Lough*

3.3. Surveys

Once the projects were chosen, surveys were distributed to gain further understanding regarding the participants and the selected projects.

3.3.1. Procedure

Prior to data collection, the four participants were presented with Participant Information Sheets and Participant Agreement Forms, giving their consent to participate in the study. To begin with, three surveys were presented to P1, designed to gather preliminary data about the projects, such as the length of the project, an estimate cost for the project, project platform and interactions. The next set of surveys related to the demographic data of the participants, capturing information such as their age, gender, role, time within this role, how many projects they have participated in whilst in this role, and their contributions towards the investigated projects. The surveys were created with Microsoft Forms and distributed to the participants via email. Results for the participant demographic surveys is discussed in Section 3.2.

3.3.2. Results

Seeing Ireland was a small to medium sized project that launched in February 2022, with a turn period of four months. This project was designed to be run via a web browser, with the methods of interaction being in-experience navigation markers or using the WASD or arrow keys.

Beyond 2022 - Virtual Record Treasury is a medium to large project which began in December 2016 and is currently an on-going project, initially launched in 2022. This project has deadlines for new content for June 30th annually. This project has been ported across four platforms during its development, with a version for the Oculus Rift, an AR mobile demo, a PC-touchscreen experience before becoming a web browser based experience. For the web-based version of the interactive virtual record treasury, mouse and keyboard navigation is used. The user can use WASD and arrow keys to navigate, as well as clicking on navigation markers. Within the VR version, the standard VR teleporting mechanic is used for locomotion.

Legends of the Lough is also a small to medium sized project and is part of a series of applications commissioned by the Mid Ulster District Council (MUDC) in 2020. P1 estimated that this application was completed over the course of a year. This application is designed for mobile devices and uses augmented reality, using the Unity engine. In terms of interaction, Legends of the Lough uses image-based unlocking features, GPS tracking, and AR spawning with tracking markers.

3.4. Semi-Structured Interviews

Following these surveys, the participants were invited to complete a series of semi-structured interview regarding each of these projects.

3.4.1. Procedure

Each interview was between thirty minutes to an hour, with some participants having multiple interviews per project.

The participants were asked the following questions with additional prompts when necessary:

1. *Can you describe the project "<project name>" for me?*
2. *Can you tell me more about the client for this project?*
3. *With regards to your client for this project, can you talk to me more about who you worked with on their side and your interactions with them during the duration of this project?*
4. *Using Miro board, could you sketch a flow diagram of the steps taken for this project, the way you understand it?*
5. *For each of the steps of the flow diagram:*
    a. *Can you describe the beginning of this stage?*
    b. *Can you describe what occurs during this stage?*
    c. *Can you describe how you know this stage is complete?*
    d. *From Noho, who is involved in this stage?*
    e. *From the client side, who is involved in this stage?*
    f. *Can you describe the tools used during this stage?*
    g. *Would you consider this stage to be unique to this project?*
    h. *Can you describe the collaboration between yourself and the client during this stage, if there was any?*
6. *Would you describe any of these stages as a bottleneck?*
7. *Do you think any of these stages could be modified with the addition of a different tool or piece of technology?*

The semi-structured interviews were conducted via Microsoft

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Teams. They were recorded to be audio transcribed, with each individual's perspective of workflows recorded using flowcharts created using Miro Board for further analysis. Between the four participants, nine sets of interviews were completed over seventeen sessions, with a span of close to 14 hours of semi-structured interviews were completed, resulting in 123,197 words across all processed transcripts.

3.4.2. Results

Once the interviews were completed, the flowcharts created during question five were extended based on the extra information gathered during this line of questioning. Information regarding tasks, individual developer involvement (where possible), individual client involvement (where possible), what tools where used, and collaboration that took place during the stages, where applicable, were collected to form these extended flowcharts.

Individual flowcharts for each project were then merged into one flowchart for each project. This was done based on several factors, such as the grouping similar tasks under one umbrella term, matching where participants appeared in other participants' flowcharts, and looking for similarities between flowcharts and matching them together, using the flowcharts created by P1 and fitting the flowcharts of P2, P3, and P4 within theirs, due to P1's position as the company's Managing / Creative Director, and therefore being able to give the most comprehensive flowchart. Once the individual flow charts were merged, these were then further condensed into one overall flowchart of the steps taken by the developers when developing a cultural heritage application. This was based on looking at similar steps that occurred across each combined flowchart, or single steps that were deemed significant. The final flowchart can be seen in Figure 2 and will be discussed further in this section. There were no major discrepancies between the individual flowcharts.

From looking at the three models, many similarities became apparent, such as the projects beginning with idea generation or a brief, each component (such as application, video, or website) of the project having some form of a design phase and a development phase, for the most part. Some stages were only mentioned once during a pipeline (such as the project support stage from Seeing Ireland), but from the description of that stage, was interpreted to be standard across projects conducted by the developers and was therefore included in the pipeline. Once these stages were identified, they were combined under the same headings and given their overall task name, such as "Project Idea" or "Brief", and had their tasks, tools, developer studio members, client collaborators and collaboration compiled together.

3.4.3. Final Model

The derived model is split into the follow stages and sub-stages:

Pre-Development: Prior to beginning development on a project, there are the four stages where the idea is created, defined, and designed. Additionally, assets from previous projects are sourced.

Project Idea: From the models, it became apparent that the first stage of the pipeline is the **Project Idea** stage, with both Seeing Ireland and Legends of the Lough starting with some form of idea generation. Here is when the idea is proposed, either from within the developer studio or from the client. Tasks here can include feasibility checks, concepting, how to complete the project and proposals, quotes, and costs. Client tasks can include contacting the developers with their idea and agreeing to employ them.

Brief: Following this, each model had a stage where the project brief was discussed, therefore the next stage of the pipeline was labelled as **Brief**. Tasks could include brainstorming, how to create the application, aesthetics, what the client wants, and getting a general idea of the project. Client tasks can include exchanging resources with the developers.

Carry Over: Another prevalent task, particularly during the Beyond 2022 - Virtual Record Treasury, was sourcing assets from previous projects. This stage was labelled as the **Carry Over** stage. Tasks could include getting previous assets and planning the project from previous experiences. Client tasks here can include helping to decide on what the app should be like.

Initial Design: Following on from this, each model had stages of design, concepting, and wireframing mixed in together. Therefore, the next stages in the pipeline were labelled as **Initial Design** with substages of **Concepting**, **Wireframing**, and **Storyboarding** with the aim of clarifying these stages with the focus group. Tasks within these three stages include figuring out the technicalities, sketches, moodboards, storyboards, creating wireframes, creating aspirational concepts, and determining if the project is indeed possible. Client tasks here include planning their portion of the application or project. During the focus group, these three stages are more accurately represented as one stage and included storyboarding. The final model was edited to reflect this.

Development and Production: Initially called "Design and Development Stages" and renamed during clarifications during the focus group, this stage breaks down into a further three substages:

Software Checks / "R&D": Several mentions were made to checking decisions made on tools to be used. During this stage, tasks include determining what type of technology is to be used for this project, updating older projects that used similar technology to see if they still work, and if there are updates to these technologies, then what the technological jump from an older version to a newer version is like.

Design: The design phase is where the final design of the project occurs and can vary wildly depending on the contents of the project. Tasks can include sketches, early testing, designing more wireframes, bringing in external advisors, proposing ideas, designing assets, pitching styles, and a variety of other tasks that may be pertinent to designing websites, application, videos, animations etc. Client tasks may include providing or deciding on content and making or meeting targets with the developers.

Application Development: Similar to the **Design** stage, the **Development** stage can vary widely depending on what was is being developed and is split into a further four stages:

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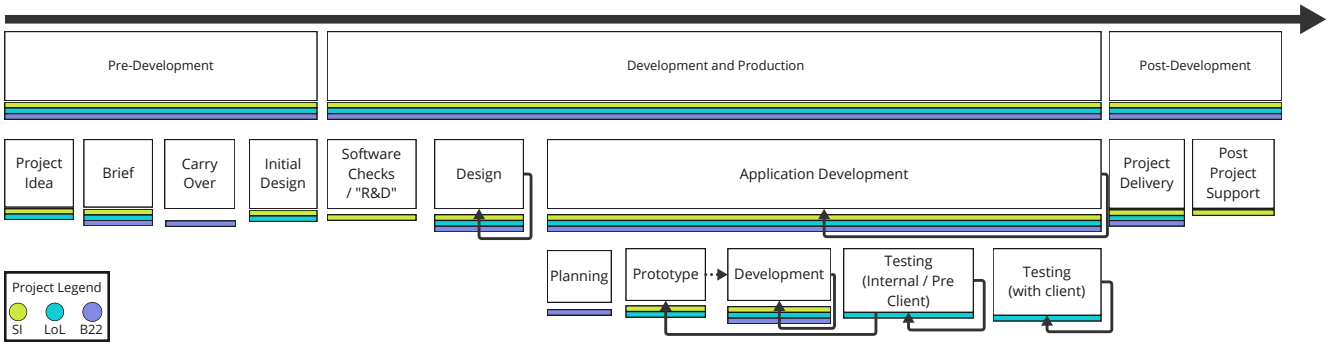

Figure 2: *The final model derived from the interviews with the developers, with coloured bands representing where individual projects appear, with additional changes given during the focus group.*

Planning: Tasks primarily include working out how to accomplish the project, working what needs to be done and how it needs to be done, and if any adjustments to be made if previous work is to be carried over.

Prototype: Here the initial prototype for the application is created. Tasks could include assessing what needs to be done, creating the prototype, getting enough functionality completed before deadlines, re-use of assets and internal testing. Client tasks here could include gathering resources to pass along to the developers.

Development: This is the stage where further development of the application occurs. Tasks could include general development of the application such as the functionality, integrating other systems, co-design with clients, implementing designs, creating additional content, creating proofs of concept, and testing as needed. As with the **Design** stage, tasks can vary depending on what the project is. The client tasks here could include co-design, data entry, gathering resources, giving feedback and advice, confirmation of project names/SEO/keywords/social media, passing along expert knowledge, showing of the created work, and creating demos of their own.

Testing (Internal/Pre-Client): This is an initial stage of testing, before the client fully gets involved with testing of the application. However, it should be noted that the developers will be testing internally on the prototype throughout development. Tasks could include internal, mock, and in-situ testing of the application, receiving change requests and feedback, implementing these changes and then cycling through this until the client receives their version for testing. For this iteration of testing, the project would be first tested in-house, with change requests and new features coming from this internal testing. These would then be implemented and iterate until the prototype is then presented to the client for feedback.

Testing (With Client): This stage follows on from the previous testing stage, with a similar arrangement of tasks. The main difference is that this stage starts with changes and new features, based on the feedback from the clients, into internal feedback, back into client feedback and then cycling back around into internal feedback. Within both testing stages, the client tasks could be co-design, testing and giving feedback and giving content.

Post-Development Stage: Once development on the project has completed, the final project is delivered to the client and long-term support of the project begins.

Project Delivery: Another common stage between all three models was having the project be finally delivered to the client, be that installation, uploading to app stores or a launch event. This stage was labelled as **Delivery**. Tasks here include delivery the final product to the client, potentially creating assets for launches and to begin project monitoring. Client tasks could include running launches and providing login and details for the app stores where the application should be launched, if needed.

Post Project Support: Finally, the pipeline ends with **Post Project Support**. Whilst this stage only appears within the Seeing Ireland Pipeline and was only mentioned by P4 but was identified as a standard part of the projects undertaken by the development studio. Tasks can include long term maintenance, such as server scaling, management, analytic reports, and security updates, as well as bug fixes as reported by clients. This stage is an on-going stage with no real end unless the client takes full control of the project. Client tasks in this stage could include communicating bugs to be fixed or requesting analytics for their application.

This model shares similarities to Agile software development methods, such as *Extreme Programming*,*SCRUM*, and *Feature Driven Development* [ASRW17].

3.5. Bottlenecks and Stage Modification

The derived codes relating to bottlenecks can be seen in Table 1 and were inductively coded using thematic analysis within the responses. The most reported code was **No Bottlenecks**, which can be attributed to a variety of factors. Participants noted that if the project is straight forward, the job is small and easy to accomplish or if they use their pipeline all the time, then bottlenecks are unlikely to occur. Additionally, the client being able to effectively contribute and do their tasks well also can contribute to the lack of bottlenecks. The next most reported codes are: **Deadlines**, where imposed deadlines of the current project, as well as other

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Code	SI	B22	LoL	Total
Deadlines	0	3	0	3
Inter-Company Collaboration	1	0	1	2
Knowledge	0	0	2	2
Lack of Resources	1	1	0	2
Limitations	1	0	2	3
No Bottleneck	2	1	1	4
Outside Factors	1	0	2	3
Project Dependent	2	0	0	2
Redoing Steps	1	0	0	1
Time	0	1	2	3
Waiting on Assets	1	1	0	2

Table 1: *Codes for question 6, with projects they appear in*

concurrent projects can cause bottlenecks; **Limitations**, where participants believed that they reached some kind of limit where advancement could not be made, such as technical limits or lack of man-power; **Outside Factors**; such as the client causing a bottleneck with not being able to do their tasks quick enough or time taken for applications to complete processes such as app store submission; and **Time**, which refers to the limits of the working day and how long implementation can take.

Code	SI	B22	LoL	Total
A - Adding New Tools	0	3	0	3
B - Automation	3	2	0	5
B - Efficiency	7	0	0	7
B - Existing Software Issues	0	4	4	8
B - Human Element	0	1	1	2
B - Longevity	0	1	0	1
B - Nothing Else Needed	0	1	2	3
B - Technical Limitations	0	2	1	3
B - Using Best Tools	0	3	0	3
B - Visualisation	0	0	1	1
V - Lacking Resources	0	2	0	2
V - Not Technical Enough	0	1	0	1
V - Testing	1	0	2	3
V - User Experience	0	2	0	2

Table 2: *Value coding for question 7, with projects they appear in. A = Attitude, B = Belief, V = Values*

The derived codes relating to how stages could be modified can be seen in Table 2 and were inductively coded using value coding. The most prevalent is **Existing Software Issues**. This refers to issues with the software they use, such as usability or functionality issues, versioning mismatches, or concerns about the viability of certain software or approaches. The next most prevalent code is **Efficiency**, which refers to making the workflow more efficient, such as by taking steps to not redo previous steps or making tasks easier to accomplish. The third most prevalent code is **Automation**, which refers to automating some tasks. This shares some overlap with **Efficiency** where comments are made towards automatically exporting from one software into another, automating tedious jobs that can take away from other areas that would need the development time (such as testing or changing all fonts) or using AI to create one area and having an expert make further changes. Another area of interest are the codes: **Nothing Else Needed**, which refers to participant's believing that their pipelines need no improvements and worked perfectly fine, therefore not needing anything else; and **Visualisation**, which refers to visualising the Wireframe stages. However, P1 notes that it would be quicker to do that within the final chosen software, and it may not be useful for them.

After the analysis and creation of the final model, it became clear that there were some aspects that needed to be clarified, such as the similarities and differences between the **Initial Design**, **Concepting**, and **Wireframing** stages. Another aspect that needed to be clarified was to be sure that the names of the stages were correct and accurate, as well as making sure that all stages were represented, and none are missing. Prototypes and demos are both mentioned, but there was no distinction between the two. It is expected that developing an application would have a cyclical nature, therefore having that be represented and accurate within the model is important and required clarification. Finally, it was not clear when the prototype moved into a more refined version or into full design or development. These questions became part of the focus group and are discussed in Section 3.7.

3.6. Mixed Reality Collaborative Authoring Application Concepts

Based upon the derived model of the development and collaboration between the developers and their clients, the identified bottlenecks, and the potential gap in the collaborative prototyping stage, three concepts of collaborative authoring tools were designed. These concepts target the design and prototyping stages of the derived model, as well as addressing the **Efficiency**, **Visualisation** and **Automation** modifications codes by providing a mixed reality environment to visualise, partially automate and improve the efficiency of developing a cultural heritage exhibition or application . Despite the high frequency of **No Bottleneck** codes, it is hoped that the bottlenecks of **Time**, **Deadlines**, and **Limitations** will be improved by these concepts.

Concept One - Developer and Client Led

Concept one has both the developer and client working in tandem within a mixed reality environment to develop a cultural heritage application (such as a virtual museum). Both parties would be able to design and prototype in the mixed reality space, with the developer joining the client's space via mixed reality, so that all are occupying the same place, where the cultural heritage exhibition would be taking place. The client and developer would work together iteratively, with the developer taking the final design, exporting, polishing and finalising outside of the application, with a late-stage prototype of the application being viewable within the authoring application. Both parties would be given access to a basic pack of environment models and a basic, easy to use programming system (such as using drag and drop) to allow for simple functionality. Outside of the authoring tool, the developer would be able to upload 3D models or images to a separate repository that would allow them to be imported into the mixed reality environment. Additionally, there

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would be a tool to allow annotations to be made to the environment for further note taking, comments and feedback.

Concept Two - Client Led
Concept two has the client taking the lead in the process and acting as the prototyper/designer. The client would be provided with a mixed reality environment, using a scan of the location where they wish to hold/develop the exhibition in. Within this environment, they would be given access to a basic pack of environment models in order to build out their desired cultural heritage exhibition prototype independently. They would also have the option to import simple 3D models or images of their artefacts via separate repository, that would be used as placeholders for the final virtual museum. The client would be able to add annotations to leave notes for themselves and the developer, such as denoting the desired interactions for an exhibit. The developers would be able to join with the client in mixed reality and view the experience that they have prototyped, make comments, give feedback based on their own experiences or ask further questions. Once both parties are happy with the design/prototype, the developer would export the prototype from the application, then develop, polish, finalise, and deliver the final product to the client.

Concept Three - Developer Led
Concept three is similar to concept two, with the developer taking the lead of designing/prototyping within the application. Based on the client's brief, the developer would prototype/design the application within the mixed reality space, using the client's environment to build in. The developer will have access to a pack of environment models that can be placed around the virtual space, as well as a simple programming system for implementing basic interactions and functionality. Once the developer has designed/prototyped the application, the client would be invited to visit the mixed reality space, view the design/prototype, and give the developer notes and feedback, using an annotation system. The developer implement the requested changes and then bring the client back in for another round of discussion and feedback. To assist with this, the application would have a versioning system to show the client various versions of the design/prototype. Once the client has signed off on the design/prototype, the developer would export the final design/prototype, finalise, and deliver the final product.

3.7. Focus Group

To confirm the accuracy of the derived model and to discuss the concepts, the participants were invited to a focus group.

3.7.1. Procedure

P1, P3, and P4 were invited to participate in a focus group for further discussion. P2 was not invited back, as they left Noho after the interview sessions. During this focus group, the models of Dean, Popoli and Derda, and Davies (see Section 2.1.1) were presented and they were asked to compare them to their project's lifecycles. Following this, the final model was presented to the participants who gave their thoughts and were asked a series of follow up questions about aspects of the model that needed clarification and/or confirmation. Once this was complete, the participants were asked further questions about the prototyping, design, and collaboration stages of the derived model. Finally, they were presented with three concepts for collaborative mixed reality authoring applications and asked to give their thoughts. The focus group was conducted via Microsoft Teams and last one hour and 15 minutes, with a transcript of 10,830 words.

3.7.2. Results

Once the participants had been presented with the models, the consensus was that these models mostly reflect their process of creating cultural heritage applications. P1 notes that, in most instances, they are not involved in assessment phases, as that is usually left up to the client, whereas P3 interpreted the assessment stage as more internal, with the project being analysed, identifying lessons being learned and what can be done better next time. P4 also noted that occasionally they may be involved in part of the management areas, by running workshops with the client. P1 concludes with deciding that they are evaluating throughout the project.

Participants felt that initial derived model was an accurate representation of their process, with P1 noting it's similarity to the process for animation or film production. It was also noted that other developers may have minor variations in the process, as the process is fluid and there is no one-size-fits-all approach. The initial changes proposed by the client were minor. These changes were to rename "Design and Development" into "Development and Production". Additionally, the "Initial Design", "Concepting", and "Wireframing" were merged into one stage, and had "Storyboarding" added into the stage. It should be noted that this may also be a project dependent change. P4 noted that the visual design could also happen after development, with P1 suggestion the addition of an interface design stage may be beneficial. P1 explains that P4 may sometimes use a wireframe to visualise to the client and then the final design, in terms of the look and feel, can come later. P1 and P3 also note that they sometimes cannot wait for the final designs to be fully created before starting development, as it may change several times during the progression of project.

Regarding the differences between prototyping and demoing, P1 notes that they do not see a difference between them, explaining further that they prefer to build early for testing purposes. P4 agreed with them being the same, with having multiple versions with various functionalities and then combining these versions at the end.

When asked about the iterative nature of the projects, P3 said that the presented model was accurate, restating the fluid nature of application development and how it cannot be "bound" to a fixed structure. P1 also noted that the iterative nature is just within the development phase with considerable circling back to previous stages within the development. Additionally, it was noted that if they cycled back into the concepting stages from a later stage, possibly due to a discrepancy between what the client wanted and what was developed, therefore delaying the project. P1 further continues by explaining that withing the concepting stages, that is where the general idea of the project is defined and should not be significantly changing after this stage.

With regards to collaboration, P1 clarifies that they often have two different clients on a project, such as the exhibition designer

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and the museum. P1 further clarifies that collaboration occurs throughout the entirety of the project. Depending on the client's pre-existing relationship with the developers, clients may directly contact the relevant developer with change requests. P1 noted that the level of client involvement is dependent on the client, with some clients participating in co-design more than others. P3 adds that interacting with the client happens in the development stage, more specifically within the cycle of sending versions of the application to the client and receiving feedback. They also mention clients can be involved in the pre-production stage, where clients would send resources and materials.

The final area for clarification was to define at what point in the process prototyping becomes full design or full development. P3 notes that the prototype is what they call the first version that of the application that works well and can be tested. Once it is tested, then this prototype is refined more with new additions. P1 adds that they have different versions of the application until the project is finished, with these various prototypes being the basis for presentations. When the researcher described this process as a "fuzzy move into development", P1 agreed.

When presented with the three concepts in Section 3.6, concept two was deemed unsuitable for many of the clients, due to the participants feeling it may be too technical or the clients designing or prototyping unfeasible applications. P3 felt that concept three may be the best, due to their existing knowledge with the technical aspects of application development and 3D environments. They also felt that concept one may give the clients too many options with what they can do, expressing a concern that development time could be taken away from the project to teach the clients how to use the application. P4 took this further, suggesting that after a few iterations using concept three, then using the joint editing features of concept one to allow for the client to make small changes. P1 also expresses an interest for the client joining them within the 3D environment.

Potential use cases of these concepts were devised, such as using them to design a virtual space or exhibition, showing where to place content, and presenting content within the virtual space instead of showing it on a screen, thus enabling real-time collaboration and co-creation by leveraging the MR capabilities. P1 noted that it would be useful for virtual museums, to be able to walk around the exhibition space and point out where content should be as well expressing that they would like to do more with the clients and 3D, stating it would be helpful if the clients could join them within the environment. Another use case was physical exhibitions, using this application to conceptualise the hardware in the physical space before committing to installation.

P3 noted that the authoring application would unlikely be used in a large outdoor space that has unclear boundaries. Another limitation may be the inability to demonstrate functionality for some applications. Additionally, P3 was unsure if there would be an advantage to using a mixed reality environment for general development but noted that in the case where they are developing a project with a virtual environment, then it may be beneficial.

Participants were also asked at what stage they would stop using these concepts. P3 felt that the authoring application could be used until the placeholder objects need to be replaced, or tasks such as rendering or light baking begin. P1 added they would exit the authoring application once the project has been defined and everyone agrees with the direction of the application. P1 further explains that if the app were to be for designing, then they would look to exit the authoring app in the early stages, to allow for full development to begin sooner.

Participants were asked for their thoughts about authoring interactions needed while using the tool and user interactions that would be used by the end user. P1 mentioned interactions such as placing and moving content or changing colours of light would be needed. P1 highlighted that it would be beneficial to have user interactions if possible but also acknowledged that it might not be worth the time to develop these in an environment that the final application may not be used in. P3 agrees with this, stating that it might not be feasible to have all the user interaction within the authoring tool. P4 suggested that it might be useful to be able to interact with webpages within the application, such as using them to simulate a touchscreen. P1 noted that this would be beneficial for development of web-based applications.

In the absence of implementing full user interaction, an annotation system was proposed to the clients with the three app concepts. P1 agreed with a system of adding notes or videos to annotate the environment. P4 agreed with this, comparing the system to their current process of using Miro Board, adding that it could be used for bug reporting as well. P3 also makes the comparison to Miro, adding it would be beneficial to use within the virtual environment but not beneficial to go back to review these notes once development has progressed past the authoring application. P1 and P3 suggested using text or audio clips to present the annotations. P1 further suggested the use of an AI chatbot to manage the annotations.

4. Discussion

From the interviews, surveys, and focus group, a model was derived that accurately encapsulates Noho's development process, as determined by the participants. The research team concluded that the areas that would best fit a mixed reality collaborative authoring tool would be the **Prototyping** and **Initial Design** stages. These stages were chosen due to the identified prototyping process, where the first prototype is presented and then goes through multiple iterations and is presented to the client. Using this tool during this stage could be beneficial, as the clients could be involved within the prototyping process, therefore participating in co-design. In line with P1 and P3's comments relating to prototypes in Section 3.7, this application could allow for rapid prototyping by both the clients and developers, as well as allowing these prototypes to be presented to the client. This tool could be used to prototype virtual museums/exhibitions, which would then be taken by the developer to be completed and delivered. Additionally, using the mixed reality component, the tool could also be used to prototype a physical exhibition, with both parties designing and prototyping the exhibition together, before committing to an exhibition or layout. In terms of functionality, concept three (see Section 3.6) will be followed, with some of the collaborative aspects from concept one being included, such as allowing the user to make simple modifications themselves and view the prototype when they would like to. The developer would take responsibility for developing the prototype and pre-

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senting the prototypes within the application. An annotation system would be required, allowing the user to make either textual or voice-based notes within the environment, based on suggestions from the participants during the focus group.

5. Conclusion and Future Work

In this paper, the results of a user study into Noho's process for developing cultural heritage applications has been presented, with a model created based on semi-structured interviews with four members of Noho, using the Seeing Ireland, Beyond 2022 - Virtual Record Treasury, and Legends of the Lough projects. This model was split into the **Project Idea**, **Brief**, **Carry Over**, **Initial Design**, **Software Checks/"R&D"**, **Design**, **Planning**, **Prototype**, **Development**, **Testing (Internal/Pre-Client)**, **Testing (With Client)**, **Project Delivery**, and **Post Project Support**.

Additionally, potential bottlenecks within the identified pipeline were explored, finding that the most prevalent bottlenecks were project deadlines, limitations regarding resources, and outside factors that are unable to be controlled. Additionally, it was discovered that it is possible for bottlenecks to occur less frequently, depending on how simple the project or how proficient they are at the task. Alongside this, possible modifications to stages were discussed, discovering that areas such as efficiency, automation, or visualisation could make the development process more efficient, as well as discovering that, in some instances, modification did not need to be made. This model was presented to the participants in the form of a focus group, with them suggesting changes and giving their opinions on the accuracy and giving clarifications.

Following these, three collaborative mixed reality authoring tool concepts were devised, and presented to the participants in the form of a focus group. These concepts were discussed with preferred concepts stated, use cases devised, potential limitations, how they would use such an application, when they would stop using the tool, and the interactions that would be within the system.

In the future, further studies will be conducted with museums and developers, with the aim to understand their thoughts regarding the derived model, the presented application concepts, the use of mixed reality and other technology, collaboration and prototyping. It is hoped that an collaborative mixed reality authoring tool will be defined, which can be then be prototyped and further studied.

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