

Mixed Reality Co-Design for Indigenous Culture Preservation & Continuation

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Figure 1: Left: Entrance to the marae (wharenuī in the background); Center: User exploring the 3D reconstructed marae; Right: Screenshot of reconstructed marae as experienced by user.

ABSTRACT

As a result of urban concentration, colonisation, increased physical distance from tribal homelands, and globalisation, many indigenous people, including Māori, are seeking digital solutions to connect to their culture and identity. Through co-design, close collaboration with our indigenous partners, and careful consideration of cultural context, we show that mixed reality experiences can be an effective mechanism for the growing diaspora of Māori to access and experience their language, genealogy, families, histories and knowledge. Inductive analysis of semi-structured interviews highlights the importance of cultural values and context in this experience, and confirms that this approach can support connections to community and culture. Our work is deeply embedded in a particular indigenous group's context and culture, but we believe that it holds important lessons that can generalise to other groups. In particular, collaborative co-design and recognition of cultural values throughout the project are essential for producing experiences that meet the needs of specific communities, and that reflect and respect their culture and worldview.

Index Terms: Mixed Reality—Virtual Reality—Application—Field Studies; Presence—Co-presence—Qualitative—Indigenous;

1 INTRODUCTION

Māori are the indigenous people of New Zealand (NZ), arriving in NZ sometime during the 13th century [35]. They have their own

ways of recording, retaining and maintaining experiences, history, religion, identity, culture, genealogy, practices and knowledge, through a strong oral tradition [13]. Passed from one generation to another, this knowledge base was mnemonically learned and systematically embedded in this oral tradition (kōrero tuku iho). This oral tradition was spread across all forms of knowledge, culture and language (i.e. whakatauki/whakatauaiki (proverbs), maramataka (lunar calendars), pepeha (tribal saying, mottos, formulaic expressions), waiata (songs/chants) etc.), incorporated into practices, and carved into wharenuī (meeting-house) [33].

Consisting of a complex of buildings including the wharenuī (meeting-house) (see Fig. 1), wharekai (dining hall) and outdoor space, the marae is seen as a focal point for many of these cultural and language-centered regeneration and revitalisation activities. Used as a communal, social, cultural, and spiritual space to greet, meet, eat, celebrate and debate, host visitors, the marae is a critical domain to share, grow, learn and experience local histories, stories, knowledge, language, customs, culture and artforms, and genealogy. In the present day “when Māori gather on their tribal marae (ceremonial meeting-grounds), the oral legacy can be heard in speeches, songs and prayers, and in the performative, metaphorical and esoteric character of their language. If a ceremony is held in an ornamented meeting-house, its carvings and decorative panels are based on the store of knowledge preserved in the tradition. Even if a meeting-house is unadorned, its name, the name of the nearby dining-hall and ancestral names across the surrounding tribal landscape, together with the histories of what gave rise to them, have their source in oral traditions” [13].

Following the signing of the Treaty of Waitangi in 1840¹ [30], Māori society has been significantly shaped and changed by increasing migration, industrialisation, urbanisation, colonisation, competing religious beliefs, and mainstream educational practices. Successive governmental policies of racial amalgamation, assimilation, and integration have jeopardized and endangered this oral tradition [32]. Many years of these changes have increased physical distance between Māori and their marae. However, since the 1970s, there has

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¹This treaty is a constitutional document aimed at establishing and guiding the relationship between Māori and the Crown in NZ ([more info](#))

been a large number of grassroots revitalisation initiatives aimed to secure the survival of the language and cultural domains including the introduction of Kōhanga Reo, Kura Kaupapa Māori and Whare Kura [30]. More recently, Māori are seeking digital solutions to maintain, interact and connect with their marae and its social and cultural associations. Although videos do provide ways to record many of these cultural and language-centred activities, this digital medium does not align with their ethos to physically be face-to-face (kanohi kitea). Additionally, while one can learn customs and values (tikanga) via online video calling this approach is not really considered the best medium to undertake this type of learning, as these are normally taught through observation and experience at the marae around elders and knowledge holders. Hence, being present and co-present around others at the marae is important for strengthening cultural identity, connection, and continuation.

Virtual and mixed reality (VR and MR) techniques lend themselves to more “naturally” enable indigenous culture preservation and continuation, because they support verbal and non-verbal forms of communication and interaction. Additionally, it allows for the reconstruction of environments, objects and the re-enactment of situations, and can produce a sense of presence and co-presence paramount to authentic cultural experiences. Our research project [18, 21]² aims to provide an MR experience that draws on Māori protocols and worldviews for preserving and sharing knowledge, language, and culture through a virtual medium. It is important to note that customs, values, and knowledge differ between regions and iwi throughout NZ and our project is in collaboration with one specific tribal community.

We provide insight on developing a MR application co-designed in close collaboration with our Māori partners. We begin with a general background on some core Māori concepts providing a premise for the cultural aspects covered in this work. We then present our tailor-designed and developed application, a milestone in the collaborative project, which allows our partners’ marae community to experience a sense of “being there” at their virtually reconstructed wharenui and a sense of “being together” with a recorded 3D storyteller. With our application, these users can experience stories within the wharenui. We carried out an empirical study exposing our co-designed system to a sample of our target population and conducted semi-structured interviews to gather feedback on the connectedness they experienced while using the application. The method of General Inductive Analysis was used on the interview transcripts to summarise the key themes and values and their MR experience. The themes derived through this process provide some initial concepts linking MR experiences to Māori experiences and values.

2 BACKGROUND

“A culture cannot be understood without reference to its worldview as this is the basis for core values” [6]. To be able to understand the complex relationships between Māori concepts and Mixed Reality concepts, we start with a short overview of some of the core Māori concepts that have emerged as part of the discussion with our Māori partners’.

2.1 Core Concepts

One of the core concepts discussed by our participants is the notion of whakapapa (genealogy). This type of knowledge is highly personal as it legitimizes one’s position within their whānau (family), hapū (subtribe), and iwi (tribe) [10]. More importantly, “it provides Māori their identity within a tribal structure and later in life gives an individual the right to say, ‘I am Māori’ ” [14]. It is this fundamental understanding of descent and whanaungatanga (kinship and attaining/maintaining relationships) [3, 17] which provide Māori with an understanding of who they are connected to, who they are and where

they come from. Another concept is that of tūrangawaewae, which is often described as ‘a place to stand’ [14]. These are places where Māori feel especially empowered, connected, or at home [23]. Having oral traditional roots, tūrangawaewae is significant as it conveys the notion of place and connectiveness.

Customarily, the concept of whanaungatanga is about the interconnectedness and relationships through whakapapa [17]. The concept also “extends to include non-whakapapa based relationships, such as bonds among those who are working together towards a shared purpose” [34]. For example, our relationship with the marae community enabled us to bond through whanaungatanga through regular visits and dialogue. Regular visits in our case included Waitangi Day celebrations, community days, and demo events as a means to share and give back to the community. Genuine research collaboration with Māori cannot proceed without the support of local iwi and hapū and a high level of mutual trust.

Commonly, whanaungatanga is referred to as the “natural course of socialisation” [17]. However, there are social “rules”, or tikanga [3]. This refers to the set of cultural practices and customs that guide and inform behaviour in various contexts [15] - the most common one being customs for social interactions. Tikanga has been retaught and reinterpreted through generations [14] and is always adapting and evolving through time. The marae is a culturally significant site and through genealogical links and connections to the land that marae are built, it provides a place for individuals, hapū and iwi to ‘stand’ regarding their identity. Alongside this ‘footing’ come their privileges to participate and use the marae for ceremonial and social purposes. There is also an obligation to assist in the work of the marae. For such a sacred place, one needs to be welcomed on if one is not affiliated with the place, through a welcoming ceremony called a pōwhiri.

2.2 Māori Diaspora

Māori urbanisation began around the 1920s. At that time approximately 80% of Māori still dwelled in their rural tribal areas [7]. Mass urbanisation commenced around the 1950s and 1960s [10] due to post World War II economic conditions, increased employment demands [16] and a government policy referred to as ‘pepper potting’ which saw the dispersing of Māori families throughout urban centers among non-Māori neighbours [28]. The 2018 census showed that there are more than 770,000 Māori living in New Zealand, which is approximately a 37.2 percent increase since 2006³. Despite this population growth, there are fewer people who live in their tribal areas as more and more Māori build their lives around major cities. As repeated generations become less physically connected to their marae, many of the ‘traditional’ mechanisms of sharing, growing, learning, and experiencing their identity becomes difficult to access. For example, a behavioural study on 16-18 year old teenagers [10] actively seeking whakapapa information suggests several barriers that prevent them from discovering more knowledge: Te reo Māori (Māori language), isolation, and inter-personal skills. Most Māori cultural events, such as pōwhiri, are conducted in te reo Māori, and so are not always easily understood.

The isolation factor comes from not living in tribal areas and therefore a lacking connection with elders and extended families who might have more knowledge. The inter-personal skill barrier says that students are whakamā (shy to ask) and don’t want to disturb their kaumātua (elders). Although Liley’s study [10] investigates teenager behaviour, it is also applicable to adults as these barriers will persist when they become adults and apply to future generations in a repeating cycle. Another concept extending the isolation barrier is that people think that they are ‘not Māori enough’ [3]. When Māori infrequently visit their tribal areas their sense of connection to the people and place dissipates over time. Later in their lives these feelings may make them feel embarrassed, knowing that they

²Link to the [Ātea Project](#)

³Statistics New Zealand: [2018 Census](#)

don't know much about their own culture, and they are often afraid to make mistakes or offend others if they do visit.

2.3 Māori and Technologies

Social networking sites, such as Facebook, are used to maintain connections to the tribal home [16]. Many marae have a homepage where they upload event information and news. Web-based interfaces for visually tracking whakapapa have also been developed by Māori firms, such as Te Ao Hunga [25]. In the North Island, the community from Te Pahou Marae have uploaded multiple 360° screenshots to Google Earth, so one can virtually visit from the entrance to the inside of the central meeting house [5]. Marques et al. [11] uses AR overlays to provide in-context storytelling with iconic iwi landscapes. Similarly, Māui Studios are using AR to enrich Māori graphic novel stories to promote Māori language [27] and LiDAR to 3D scan a marae [8]. Similar to our application, the Mataatua VR project⁴ recorded an elder speaking, using a large multiple-camera dome recording system, 3D reconstructed the wharenui using 3D laser scans, and played the kōrero back in VR so families can listen up close.

Most of these examples are either ongoing work or incomplete projects outsourced to external companies. The related work and efforts require specialised equipment and knowledge, often to be contracted in. What all these examples illustrate is a focus on presenting the experience without fully interrogating how these MR technologies might be used for culture continuation. Our approach is quite different—in close partnership we co-design an extended MR system to empower Māori to share and tell their stories in an appropriate context with the ultimate goal to make non-Māori partners in this process unnecessary.

3 MĀORI PRESENCE APPLICATION DEVELOPMENT

As outlined above, the marae is the cultural meeting place and a focal point for many of these cultural, artistic and language-centred activities. Māori have connections to their marae through understanding their whakapapa which establishes their tūrangawaewae. Frequent visits to the marae helped us to cultivate whanaungatanga and give a platform to observe and learn the tikanga from our Māori collaborators. Based on this relationship and the issue regarding Māori diaspora, we co-designed and collaborated with our Māori partners to develop an immersive application that supports a technological structure of maintaining connection and natural knowledge sharing through oral traditions in the form of storytelling.

3.1 Partnership and Co-Design Process

Before any core application development, strong levels of trust and relationships were formed with the marae. Mutual respect is expected as the standard social etiquette when meeting new people, especially, for non-Māori researchers, when meeting partners at their marae. The non-Māori partners engaged with Māori culture further by being involved in appropriate cultural practices. For example, much like when one visits a person's home, non-Māori were formally welcomed by attending a pōwhiri before being allowed to first enter the marae. This involved learning the basic protocols of the ceremony such as when/where to enter the marae, koha (gift giving), and sharing of kai (food). This gesture was reciprocated by inviting Māori partners from the marae to the technology lab to demonstrate the mixed reality 3D capture technology. This was where and when the initial co-design sessions started.

After this initial meeting, our partnership continued to develop over a period of more than three years through a *participatory co-design and iterative process*. In general, each iteration of the co-design process involved non-Māori partners visiting our Māori partners at their marae and demonstrating the new current state of the

application. During this process we gathered their feedback, discussed and interpreted their emerging needs as they experienced the growing potential in the iterative demonstrations. Cultural concerns took precedence over technical or academic objectives. This co-design cycle has been successful as this inclusive and iterative approach allows us to directly show tangible minimum viable products to our stakeholders and receive collaborative design suggestions in person—strengthening our partnership and trust.

As our partnership and trust strengthened, non-Māori were granted more permission to capture content to integrate into the application. For example, at the start of the project, it was not appropriate to take photos of the wharenui for 3D reconstruction until this partnership developed further. As a reminder, this is a sensitive place to share as it contains ancestry, history in form of artwork and stories, and is one of the core domains of Māori identity. Additionally as our partnership progressed through the co-design stages, our Māori partners began recording 3D stories together with non-Māori researchers to be added to the application. Hence, described in this paper is the current stage of our application development as a result of this successful partnership development and cultural interaction.

Permission was always sought before publicly using our Māori partner's content such as in research publications. It is also important to “give back” to the marae community as many partnerships fail after the completion of the project. In our case, multiple VR demonstration events were held throughout our co-design iterations. For example, we presented our work to the wider Māori community at the marae on Waitangi Day⁵. Other events included a Marae Community Day where our application was shown to the community school children. Our co-design team consists of three Māori leaders from the marae (one being an academic Māori researcher) and four other non-Māori researchers around NZ.

3.2 Linking Māori Goals with MR Experience Concepts

To support our Māori partners with reconnecting their dispersed community members, we co-developed an immersive application that provides a storytelling experience allowing users to virtually visit their wharenui and hear stories from their elders. The sense of presence, or ‘being there’ in a virtual environment [24] was an experience necessary to provide for the community. Hence, we 3D reconstructed the physical interior of the wharenui and placed it in the virtual environment so that one could feel being at “home”—the tūrangawaewae. The sense of co-presence (‘being together’) in the virtual environment [2, 36] was also a targeted experience for the community. Therefore, two of the marae storytellers were 3D recorded and added in the virtual wharenui so that users can interactively see their elders and listen to their story. Through these experiences, we hope to provide a way for the dispersed marae community members to maintain connection, preserving culture, and identity. The following sections describe the components developed for our application.

3.3 Reconstructing the interior of the Wharenui

The wharenui is of ancestral importance to our Māori partners and their community. Therefore, once permitted by our Māori partners, we reconstructed the interior of the wharenui using photogrammetry (3D reconstruction technique from images [4]) to be used in our application. We used several DSLR cameras with 20mm or 24mm (35mm equivalent) lenses to capture approximately 3,000 images of the interior of the wharenui. To ensure correct exposure, low noise, and consistent focus across the each image, we used apertures ranging from f/7.1 to f/11 depending on lighting conditions, and used tripods to avoid motion blurring when necessary.

We produced a 3D reconstruction from these images using RealityCapture⁶ over several iterations. ‘Normal Quality’ texture mesh

⁴Mataatua VR Project

⁵A National Day marking the initial signing of the Treaty of Waitangi.

⁶Epic Games: Photogrammetry Software



Figure 2: 3D reconstruction process of wharenui: (a) Over three thousand photos taken within building, (b) point cloud generation and mesh reconstruction, (c) third-person view of interactive, reconstructed environment with voxelised user in it, (d) user in real space, (e) user’s first person view.

reconstructions were produced and examined visually, and more images were captured of parts of the wharenui where the reconstruction lacked detail or were incorrect or noisy. Once a sufficiently complete and accurate model was produced, we used the ‘High Detail’ configuration preset to produce a high density mesh reconstruction in excess of 900M triangles, which was then smoothed and reduced in 10% increments to a more practicable complexity with 3,912,244 vertices, 1,304,101 faces. A UV map and a set of textures was then computed for the simplified mesh, resulting in eight 8192×8192 texture images (see Fig. 2).

3.4 Voxel-based Immersive Mixed Reality

Aligned with our Māori partners’ interest for sharing knowledge through oral traditions in the form of storytelling, we volumetrically and acoustically recorded eight stories and integrated them into our application so that their communities could interactively watch and listen to their elders speak. As the two of the marae storytellers are also leaders of their marae, being co-present and hearing stories through them should feel authoritative, credible, and close to reality (when physically at the marae). To support this feature, we developed our Voxel-based Immersive Mixed Reality (VIMR) system. This is based on our previous work [18, 21] which employs a coarse graphical voxel visualisation for MR content (i.e., human body representations). Voxels are volumetric pixels (here cubes) spaced in a regular grid in three-dimensional space [22]. This type of visualisation has proven to achieve a high (enough) sense of presence and embodiment [19] and co-presence using volumetric recordings called voxel videos (Fig. 3b) [20, 22].

VIMR consists of one or more depth-sensing cameras (nominally three), with one computer per camera and an additional ‘VR-Ready’ computer (the ‘server’) which receives voxel data from the cameras for recording and/or rendering (Fig. 3a). An Oculus Rift CV1 or Rift S is used to render the system in VR, and the Oculus tracking system defines the ‘world’ coordinate space. A sparse octree reconstruction is produced from each RGB-D frame in real time, with the voxel grid resolution chosen so that the reconstruction consists of a

contiguous ‘shell’ of occupied voxels. RGB-D data is first registered to the world coordinate system, and the octree is constructed by pointwise insertion. The in-memory octree is then converted to a serial encoding and sent over dedicated network to the server where data from all cameras is integrated into a single octree. When at least one octree from each camera is integrated, the combined frame is considered complete, and may then be rendered and/or re-serialized and recorded in sequence as a *voxel video* (.vx file).

In-memory octrees use a child-pointer tree structure where internal nodes contain pointers to their occupied children, and leaf nodes store the voxel colour and semantic information. Encoding of semantic information is application dependent, and here we use one byte to identify invisible ‘audio’ voxels which encode the positions of the audio sources in a voxel video. Each internal node in the serial encoding is a one-byte child occupancy bitfield, and a complete serial octree is the breadth-first concatenation of all occupied internal nodes followed by a contiguous array of leaf data. Decoding a serial tree and merging it with an in-memory tree is a single simultaneous breadth-first traverse of both trees, during which the grid index of each leaf node is recovered for compatibility with the renderer.

Point clouds are aligned by rigid transform; the alignment transform for each camera consists of a camera pose component, and a refinement component. The camera pose component is estimated by hand-eye calibration [31], using a large (A1-sized) checkerboard with an Oculus touch controller rigidly attached to capture the calibration data. The pose component aligns the data from each camera in the world coordinate space which is defined by the VR tracking system. To improve the camera-to-camera alignment, we perform a refinement calibration stage; a point cloud of a static scene is captured from each camera, one camera is chosen as the reference point cloud, and the remaining clouds are aligned to the reference cloud by iterative closest point (ICP) [37].

We developed a voxel rendering (VIMR) plugin for Unreal Engine (UE), where each occupied voxel is rendered as a discrete coloured cube. Implementation as a plugin for a mature game engine affords the benefits of a complete and highly optimised scene graph, and built-in support for a wide variety of platforms and virtual reality systems. However, the plugin architecture provides only limited access to the rendering pipeline, and to work around this we use three texture buffers and a set of pre-generated mesh cubes; two RGB8 buffers store the low and high bytes of the voxel grid index and the third stores the colour. The grid index is used with the voxel size to recover the world position of the voxel, and a vertex shader is used to shift, scale, and colour each of the cubes appropriately. While this approach lacks absolute computational efficiency, we chose this approach to allow integration of the voxel plugin with arbitrary UE projects, and to simplify portability between engine versions. This is sufficient, as with our current implementation, each voxel rendering game object can render 196,688 voxels which is sufficient for full-height human reconstructions, each requiring about 90,000 voxels at 4mm resolution (using 3 depth cameras).

3.5 Integrated Rendering System

The 3D wharenui reconstruction and VIMR plugin (for voxel video playback) is integrated into a UE v4.26.2 project on a Windows 10 system. This framework has programmable interfaces for creating logic and rendering VR using visual scripting (Blueprints and C++). This programmable logic is applied to the base class called *Actor*, which all instance classes derive from. These can be added into a visual scenegraph, called a *Level*, to create interactive virtual environments. Our application uses three default classes provided by UE: 1) *GameMode* defines the “game rules” and default classes, 2) *Pawn* is an *Actor* controlled by inputs or AI through the controller actor that possess it, and 3) *Controller* objects are used for directing a *Pawn*.

Our reconstructed model is imported as an FBX file. Its associ-

ated materials and textures are automatically generated and imported respectively. A static mesh *Actor* is also created representing this model in UE, which is placed in our application *Level* and checked for correct scale. Preliminary model reduction was applied to reduce the vertex count in UE for a better real-time experience. Our modified *VrPawn* class handles the VR interface logic, such as teleportation for traveling and raycasting for selecting voxel videos playback. Teleportation is initiated by holding and releasing the trigger on the Oculus touch controller. Using a virtual controller pointer to hover over a wharenui wall (with artwork) and pressing the trigger button starts the voxel video playback, handled by the *VoxelVideoActor*. A custom *VrController* directs inputs for this *VrPawn* interface. Both these modified classes are set for use by default in our custom *GameMode*.

4 EMPIRICAL INVESTIGATION

Ultimately, our application is targeted towards the dispersed community of our Māori partners. Although we conceptually demonstrated how VR and MR might work for their cultural practices, we were unsure if others in the community might find the approach appropriate. Therefore, a preliminary empirical investigation was conducted using our application to determine how they perceived the MR experience designed for them. Most importantly, we wanted to know how well the application and experience aligns with their customs and values. For this investigation, we presented the application to *five participants* at the marae who were all female and not part of the co-design team. Using an inductive approach [26], we then conducted semi-structured interviews and voice recorded their responses, transcribed and analysed them, and summarised them into themes to report their insights. Such methodology and scope is common-place in participatory design and social science research (i.e., [9, 12]), but less used in VR research to date. Below we describe the methodology in more detail for readers less familiar with qualitative methodologies.

4.1 Evaluation Methodology

Our empirical investigation took place in the marae complex, as part of one of our regular visits to meet with our Māori partners. We introduced our project to people around the complex and asked if they would be available and willing to try it out. If they agreed, we then led them to a separate location in the complex where the system was setup, helped them put on the HMD gear, taught them how to navigate their virtual wharenui and let them interact with the system. After they saw the demonstration, we then asked if they were willing to be interviewed and audio recorded. All participants were happy and agreed to be interviewed on the potential of the system for their community. All the interviews were conducted in a separate dedicated room in the complex. Two co-designers conducted the interviews with one leading questions and the other

Māori interviewer helping with cultural interpretations. During the interviews, we first asked how they felt about their experience as an opening question to start the interviews. We then continued with questions that prompted participants to respond openly to specific aspects of the system. Some examples are “What did you think about when you saw your wharenui virtually?” and “When you were listening to the story, what was going through your mind?”. Interview times ranged from 22 to 36 minutes.

Audacity⁷, an open source audio recording software, was used to record the interview and export as a raw wav sound files. We transcribed these interviews by using the wav files in Otter.ai⁸. Each transcript was then manually verified for completeness with the audio playback. The text in the transcript that did not align with audio playback was manually reviewed and edited by the investigator.

The transcripts were then analysed using an inductive thematic approach following the guidelines from Thomas’ General Inductive Analysis [29] and applied a thematic analysis [1]. The inductive approach derives broader generalisations, concepts, or theories from specific observations and measures [26]. Therefore, it is commonly known as a “Bottom-Up” approach (specific to generalisations). This type of approach is typically employed by qualitative methods and is well suited for exploring patterns in the data. Such patterns are presented as generalised themes and new concepts inferred from them. Through our collaborative work with our Māori partners, our application has laid the groundwork to explore potential themes bridging MR concepts to Māori experiences, customs and values. The following outlines the thematic analysis steps we took to generate the themes:

1. We read the transcripts thoroughly to get an understanding of the context discussed.
2. Once the investigator was familiar with the context, important text sections were highlighted in the transcript. These sections are commonly sentences or paragraphs that can be categorised into a low-level (specific) theme, which is usually a phrase or word derived from the section.
3. Each initial theme, along with the corresponding text segment, was added into a spreadsheet for overall theme visualisation. Each entry included a participant number and timestamp, so that it would be easier to trace back to the original transcript.
4. We then counted the number of unique low-level sub-themes (more than 40 in all).
5. The investigator then read all the sub-themes to identify similarities between them.
6. Once the 40 sub-themes were identified, a list of sub-themes and a subset of the extracted text segments were given to four other researchers to review. Each reviewer was tasked to match the developed categories to the text sub-segments assigned. These were compared to the original categories to see how much they matched. The matching percentages of each of the four reviewers to the original categories chosen by the investigator were 16.7%, 25.0%, 22.5%, and 42.5%. Because all comparisons had low percentages, the investigator met each reviewer individually to review their differences until a final consensus was reached.
7. After many iterations of generalising, the sub-themes were summarised into three high-level themes.
8. The final themes and immediate sub-themes, with their supporting text segments, were compiled into a report for final peer-review. Disagreements were discussed until a consensus was reached among all peer-reviewers.



Figure 3: (a) 3D recording of a storyteller within the real wharenui environment using portable three-camera system; (b) voxel video played in 3D within reconstructed wharenui building.

⁷Audio Recording [Software](#)

⁸Online Transcription [Software](#)

Below we present the three themes that emerged from our interviews: *Customs and values (Tikanga)*, *Transfer of Knowledge*, and *MR/VR Experiences*.

4.2 Theme 1: Customs and Values (Tikanga)

Our first theme discusses how our participants considered our system with regards to tikanga, a foundational Māori concept. Tikanga loosely translates to protocol, customs, or the ‘right way’ to do things. Participants discussed how they saw our system supporting several aspects of tikanga namely being able to maintain relationships, through connecting with whānau (family/community); acting as a ‘calling’ for those who are afar; allowing for meeting face-to-face and for communicating mana (prestige/authority) and keeping the culture alive.

The relation between tikanga and technology and potential tensions that can arise were also nuanced as part of these conversations. It was acknowledged that tikanga may have to adapt to meet the needs of the community and ensure their goals are achieved and technology can support this: *“Potentially there’s going to be a shift in how we view this type of technology and how our tikanga will form around that technology because tikanga can change, ... it adapts to whatever the needs of the people are. Our ultimate [sic] is to make sure that we continue on, our whakapapa [lineage] continues on. So you will have ... old school people who’ll go: “OH this is tapu [sacred and forbidden]” and your sitting there going: “No it’s not quite tapu.” This is about ... we have lost the ability to do the story in oratory that ... my father and generations before and some of his colleagues of his generation were able to do. ... we’ve lost our language is just about annihilated so we have to try again. We have to reform ... think about the technologies that are going to ensure there’ll be no further loss of this knowledge ... our language and we have to use those technologies to do it. So the tikanga will shift to ensure that our goals will be maintained”*.

Maintaining Relationships (Whanaungatanga): Participants found our application a useful way to connect their whānau (family/community), especially for those who cannot physically be home. Through the application, dispersed family members can still be involved with their cultural practices: *“for whānau that are connected to here and they’re overseas, Covid, whānau that want to get home. AND with this kind of technology virtually, this is amazing for them because they are not missing out”*.

This is important because relationships can be fragile if not maintained [14]. A key desire for many Māori is having the ability to come home to regularly visit and meet with their whānau and the system was seen as a way to support those who are not able to do that: *“I know people who want to come down here because they whakapapa here ... but they just can’t get here so if they had a way to see and hear some of the stories, that could be a big thing for them”; “It is an opportunity to distribute knowledge around tikanga so it breaks down the walls and the fear that comes with a lot of our whānau who haven’t been privileged enough to learn the tikanga for the where”*.

Calling (Karanga): Participants further considered how the system can act as a potential calling for those away from home. Having availability to such a system would remind those who see it to come back home or at least trigger a form of interest. Here a participant outlines this feature referring to those blown in the four winds (connecting dispersed family members in all directions—north, south, east, and west): *“So it is that not just to reform a connection for those that are away and it’s a reminder, ... a karanga. It’s a call to those that have been blown in the four winds around the world. It is actually a potential karanga to draw them back in so they can come back into the physical whare [meeting house], know what they’re walking, you know, like how beautiful it is and bringing them back in”*.

A Face Seen (Kanohi kitea): Another tikanga concept associ-

ated with whanaungatanga is a face seen (kanohi kitea). When maintaining relationships, there is a strong emphasis on meeting face to face. The system allows voxel video recordings where speakers can be represented in 3D, participants are able to see the entire speaker and their faces, which was found to embrace this concept and its connection to oral traditions. Here we see a participant comment on their experiences when seeing the speaker virtually in person: *“... you get a piece of paper that tells you, this is an authority ... don’t get me wrong, the authors in there you read them and go: “wow that’s amazing”. But it’s still not oral, you don’t hear the afflictions in the voice, you don’t see the responses on the face to the kōrero [speech] sitting on the paper, say that’s not that level of connection. You see the rangatira [expert] standing there ... could say exactly the same thing that’s on a piece of paper, but I would remember them, not necessarily the piece of paper”*.

Authority/Prestige (Mana): Another tikanga concept related to whanaungatanga and kanohi kitea is mana. Mana loosely translates to the authority/prestige of a person which indicates their place in a social group. As articulated by the following participant, the system allows the user to be co-present with the knowledgeable speaker. Because knowledge is being told directly by the kaikōrero (speaker) through a recording, their authority and presence can be felt throughout their kōrero. Therefore, in this context, the source of knowledge becomes more credible in contrast to written documents. Additionally, it continues to follow oral tradition on which Māori culture is heavily based: *“For many ... young Māori when they leave here and whatever path they go on for some of us when we go to academia space, we’re expected to read the paper ... these documents that have recorded our histories, whether we agree with them or not, they’re on a piece of paper and they are deemed as authority ... And yet this isn’t how we transfer those knowledge. So you change it up and you go into a [VR] space like that. Because part of our, I guess the ethos, is that responsibility of knowledge transference sits on the rangatira [chief] path to pass over ... And so the authority doesn’t come with the reference on the piece of paper. It comes with the knowledge of the person standing there with the mana [authority] ... So being able to see that person, being able to see their authority and see them carrying out their roles as a rangatira and as a tohunga [expert] to transfer that knowledge is really important”*.

Fires of Occupation (Ahi Kā): Ahi kā generally refers to the continuous inhabitation of a place/land. Whakapapa and knowledge of place is crucial to Māori as it gives them the rights of occupation within a hapū/iwi. To maintain that physical occupation, one needs to maintain contact and be seen by their extended whānau and hapū. More importantly, the culture of the marae community needs to be kept alive. This would not be possible if knowledge, such as whakapapa, was lost. Participants suggested that the system will help people to maintain the Ahi kā and “keep the home fires going”: *“Well ... we can utilize that technology ... because it’s not uncommon for a half a dozen people off the street to come in and there’s no one here ... and that technology could be used especially with their whakapapa ... their opportunity will be there ... When there’s no one here, the place won’t be cold”*.

4.3 Theme 2: Transfer of Knowledge

Our first theme explained how participants saw the system aligning with tikanga concepts, and specifically preserving tikanga. This second theme presents how the system was viewed towards transferring indigenous cultural knowledge to the next generation, which is a key goal for the Māori community. All participants positively indicated that the system is a great way to transfer knowledge, especially to their mokopuna (decedents). Some have also underlined the practical barriers that prevent their whānau from maintaining their connection. Three sub-themes emerged from the interview discussions: taura, learning tool, and sense of security.

Rope (Taura) of History: A key concept with respect to the transfer of knowledge that participants discussed was the Taura, the Rope of History. This concept represents an acknowledgement of how Māori people are placed within the continuity of their history and their whakapapa (lineage). The passing of stories, is a way to transfer knowledge and continue the Taura and participants discussed how they saw our system as being able to support this and, moreover, considered it as the correct medium for this type of knowledge transfer. Through our system, participants viewed eight recordings of stories that described each wharenui wall. Many participants mentioned how they wanted more stories and were interested in extending stories to recording all histories related to the marae and not just whakapapa stories. Here a participant's comment highlights this point: *"It's that whole acknowledging where we are placed in the whakapapa, say in the timeline and the taura [rope of history]. So acknowledging all of these things, you know. Our tohunga up there are able to give it that story of ... the building of that whare. There's so much more, you know, how they fundraise and everything else but looking at acknowledging the whare itself. There's a huge history. There's a whakapapa right back and ultimately for this particular ... project, it's setting a mark and that taura, which will affect our generations to come"*.

Learning Tool: Many Māori teachings require in-place learning. A simple example is how one learns the tikanga around pōwhiri when attending one regularly. Participants commented on the convenience of a modelled virtual environment and how such a system would be great for in-context learning: *"It's funny I am just in the middle of doing, we run an annual art exhibition based on a theme and so each year and we've sort of revamped it and our theme next year is Tangaroa [god of sea and fish]. And so my teacher brain tells me that I want to take the kids down to collect kaimoana [seafood], talk about practices, tikanga, yeah, those sort of resources that could be available for teachers to use encompassing Māori tikanga things like that. So, yeah, definitely down to a different waterways and things"*.

Sense of Security: Using the system seemed to make participants feel secure knowing that their kids would be stronger in their identity and values embedded in their community moving forward. A goal here too is to prepare a stronger generation to lead the culture in the future. Participants noted that the system can pick the interest of the younger generations and allow the passing of knowledge: *"that's the part that interests me, that's the part that probably will stimulate people, is the fact that we are going to be able to ensure that these gifts that were passed down from generations that helped us survive ... and knowing that our kids will be stronger in their identity going forward ... It [knowledge] hasn't been lost; it's just being transferred in a different way and change. This [our application] is one way of ensuring the sustainability on the values that have been embedded in our community to inform our mokopuna [descendants] going forward"*.

4.4 Theme 3: VR/MR Experience

In this theme, we present participants' thoughts and perspectives from their direct experience with the system. These entail suggestions and feedback on technical features and aspects of the VR interface, as well as commentary on experiencing a sense of presence and co-presence. Overall, participants' immediate responses to experiencing the system were very positive, from enjoyment to feeling positively overwhelmed: *"I think that's a good way to do it ... I actually quiet enjoyed that ... I am over the moon"*; *"It's quite like I said it was really overwhelming, in a good way and not like ugh"*. Many also expressed amazement on the advancements of technology that allow for such experiences to be achievable: *"Oh, amazing, like next level actually. Just wow, it's like I am Just amazing what technology can do"*; *"I first thought I can't believe that there is technology that can do this ... so yeah just surprised"*;

"Oh no I was blown away. Okay, but every time you come back. It's got better. It's sort of gone ... leaped".

Sense of Presence: Most participants indicated they experienced a sense of presence when using the system: *"I thought it was amazing that you could be in one room [physical] and actually feel like you're in the whare ... You actually feel like you're there; ... I love seeing the wharenui [meeting house]. Yeah it was very cool; with me ... being in the virtual thing. It's like it's the same as me being here on a daily basis. It like, ... Real; The realness ... the exact look alike, recognising each wall and its clarity; When you're actually in it, like I could have stayed in there all day"*.

Sense of Co-presence: Most participants said that they felt like they were next to the recorded speakers: *"I love the fact you can popup with the speakers [anonymised names] ... I like the fact you can actually see people"*; *"They're right there and you know like I reached out to give him [anonymised names] a cuddle with a kiss"*; *"I think what probably got me [cry] was being able to see not just the whare but seeing the speakers [anonymised names] talking"*.

VR Interface: Participants commented on technical features and made suggestions about the system interface. For example, participants liked using the teleportation feature for traveling around the wharenui space; they found it helpful and easy to use: *"So, I found it. Like technically you know clearly this is the first iteration of it. But I love the idea of like even how it's structured around, you know, being able to click at any point in the whare to be able to stand, wherever you want to stand and then looking around. So I did the whole like look around, looking up. And it was really easy once I got the flow of how you do it, you know, could be because automatically you want to walk there right. So, reminding okay I'm using this to take me there so I click there but the other thing like being able to turn"*.

In terms of suggestions, several participants proposed providing some kind of help or tutorial for first time users to learn the navigation controls: *"A little bit unsure because I'm not that tech savvy, haven't done anything like that before, but you were definitely great at showing me how to work it and I felt like I could easily get the hang of it ... with time"*. One participant suggested having an option for showing labels inside the wharenui. The wharenui has many landmarks which may aid in understanding the parts of the wharenui the speaker refers too: *"Could you like have a like subtitle somewhere in there that: 'This is the Ahi kā wall', you know, like name the walls"*.

Furthermore, participants expressed a preference for a higher quality version of the voxel videos. Our recordings heavily depend on constant environmental lighting conditions. Thus, some recordings have holes in the body representation due to inconsistent depth camera exposure. This makes the voxel videos look somewhat washed out and incomplete: *"They're gonna become more clearer? The speakers' [anonymised names] Voxel quality?"*; *"No it's not disturbing I just thought that you could get a bit better quality. You know, but you know, it's just a nice to have"*.

Participants thought that the speakers looked natural if they were positioned next to the wall facing the audience: *"So that was a thing that went through my head too says, that when, okay, yep they're directly staring at the wall. Um so my thoughts were that: Oh, it's probably best if they're situated here on this angle but they are looking at the wall but more to the side and on an angle but steering at the group ... and looking at the wall, but not directly ... Yeah it's just a personal feeling"*.

Finally, it was interesting to see that participants embraced the developing technology, despite some initial reservations, as they felt it held value as the preferred medium of the next generation: *"The good thing about that is the type of technology that our future generations, our mokos, have come accustom too, which is maybe not my preferred medium but it definitely theirs"*.

4.5 Summary of Findings

Theme 1 (*Tikanga*): Participants agreed that the application aligns with many Māori social customs and values. An important value supported by the application is whanaungatanga, which is an emphasis on maintaining social relationships. Participants believe that the application is suitable for helping their dispersed community maintain their connection to home (identity, family, and community). Tied to this value is kanohi kitea (a face seen) which means their connection is best maintained co-present with others. This is supported by the application where the community will be able to see the face of their storyteller (marae elders). Seeing their faces could generate a level of familiarity with their elders, which might help boost the confidence of dispersed communities to approach them in the real life. Also, mana (authority/prestige) is said to flow through the voxel video medium, which makes the knowledge from the storyteller more credible. Participants also believe that the application can continue to ‘stoke their home fires’ (ahi kā), meaning that the marae will continue and never ‘remain cold’. Finally, it is believed that the application is a calling to those, with minimal cultural interest, and serves as a reminder to draw them back into learning their Māori identity.

Theme 2 (*Transfer of Knowledge*): Participants were supportive about using the application for transferring their knowledge. Hence, we can infer that the application appropriately presents their wharenui and stories virtually. This is also apparent because participants suggested extending the stories to other contexts, such as building the wharenui. This is valuable to them because it has the potential to acknowledge key moments in their rope of history. Participants also suggested that the application can be used as a learning tool for other parts of their culture. Many Māori teachings require in-place learning, so the convenience and flexibility of virtual content allows them to be placed in alternative environments that are often difficult to reach, such as learning the tikanga regarding collecting seafood. Through these key points about the application, participants have a stronger sense of security knowing that the next generation will be stronger sense in their Māori identity going forward.

Theme 3 (*VR/MR Experience*): The overall application and experience was positively and emotionally received by participants. When using the application they felt present in their virtual wharenui and co-present with their marae elders. This is apparent through comments like “You actually feel like you’re there” and “They’re right there [the speakers]”. Participants also enjoyed the travel and selection interface implemented for navigating around their virtual wharenui. Other comments suggested potential interface improvements such as virtually labeling parts of the wharenui. Especially labeling parts of the carvings on the wall could make it easier for the listener to know what the speaker is referring to. A higher quality version of voxel videos was suggested, but this is believed to be only for aesthetics. Participants also recommended that placing the speaker near the wall facing the audience would feel more natural.

This empirical investigation indicates that the application successfully aligns with Māori *Tikanga* and support the *Transfer of Knowledge* using virtual storytelling through *VR/MR experiences* (namely the sense of presence and co-presence). From these themes and findings, we contribute these new key concepts linking MR experiences to Māori culture:

1. The sense of presence allows Māori to feel at home and connected to their tūrangawaewae.
2. The sense of co-presence supports whanaungatanga (maintaining relationships) provides a preliminary way for kanohi kitea (being face to face). Being co-present also allows mana (authority) to flow through the voxel video recordings of the speaker.
3. The combination of presence and co-presence experiences in a MR application strengthens the ahi kā (fires of occupation),

meaning an increased sense of security towards their cultural preservation and continuation.

4. The combination of presence and co-presence experiences in a MR application is appropriate for connecting, cultural learning, and acknowledging key periods in their “rope” of history.

5 CONCLUSION AND FUTURE WORK

Decades of Māori urbanisation, colonisation and globalisation have dispersed marae communities away from their tribal home all around NZ and overseas. This has left many feeling disconnected from learning their cultural identity. Typically, non-immersive media, such as videos, are insufficient because a preferred method for Māori is to be physically at their marae and meeting their people face-to-face. Therefore, Māori have sought digital solutions to mitigate this problem by finding ways of preserving and continuing their culture using immersive technologies. In this initial milestone, we achieve this by developing an application which places Māori back into their ancestral meeting house and allow them to hear 3D stories about their people.

For other researchers and developers involved in an indigenous project, we recommend using a participatory co-design process when developing MR applications for indigenous preservation and continuation. This is because inter-cultural work is a sensitive task hence strong trust and mutual understanding is required as different world views merge to work together. This work demonstrates a successful example of cooperation as both Māori and non-Māori worked together by participating in each others’ cultural domain while developing mutual trust with time. A patient and iterative process of working prototypes, open discussions and interpretations have also contributed to achieving Māori needs. It is especially important to “give back” to their community through active involvement at the marae.

We assume that other indigenous cultures with oral traditions have similar requirements of being face-to-face in their cultural activities. Hence, we believe that using VR/MR would suit other projects involving indigenous groups. Future studies may be useful to investigate other indigenous cultures for preservation and continuation using a participatory co-design approach. Additionally, qualitative analysis methods are useful for exploring indigenous responses to emerging technologies, especially when the impact of VR/MR on the indigenous group is uncertain. As this qualitative study only interviewed a small sample, future studies would take our concepts and be further discussed with the marae community collectively.

Future work aims to incorporate tele-co-presence to bring dispersed marae community members around New Zealand into the same virtual wharenui so they feel connected to home. Eventually this would also reach global distances. With real-time remote capabilities and more content added to the application, those distant from home can learn and maintain their connection to their whakapapa and tūrangawaewae. More research is also needed to investigate whether emotional and social connections can be maintained with the application in a sustainable way. Furthermore, a hand over of the application and development process would involve workshops teaching our Māori partners about the technology. This is to ensure that our Māori partners can be empowered to self-record their own stories while making potentially non-Māori researchers and developers redundant in the future.

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