

Virtual Reality Pōwhiri—Practicing an indigenous welcoming ceremony

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Figure 1: Left: Reconstructed 3D model of the exterior path visitors take for the pōwhiri; Center: Volumetric recording of people walking the path; Right: 3D reconstructed whareniui (meeting house) with volumetric recordings of visitors and hosts

ABSTRACT

Pōwhiri is a traditional welcoming ceremony in Māori culture in Aotearoa New Zealand. Certain protocols (tikanga) have to be followed and must be learned. There is a general lack of understanding regarding this due to the scarcity of pōwhiri. The immersive and experiential nature of Virtual Reality (VR) can be used as a tool to increase understanding and confidence. We have implemented a VR learning tool in the reconstructed context of Te Rau Aroha marae in Bluff which allows for safe practice of pōwhiri before applying it in a real welcoming ceremony.

A cultural evaluation study was conducted first followed by a user study to determine understanding and confidence gains, highlighting the complexity of the topic. The user study clearly showed that the system was useful to increase participants' understanding in regards to pōwhiri as well as their confidence surrounding pōwhiri. We are confident that our experiences and key findings

from the studies can be used to drive further development of VR tools in the context of visualising cultural ceremonies.

CCS CONCEPTS

• Human-centered computing → Virtual reality; • Computing methodologies → Mixed / augmented reality.

KEYWORDS

Indigenous User Interfaces, VR Learning, Volumetric Video, 3D Reconstruction

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1 INTRODUCTION

Māori are the native people of New Zealand, and, like other indigenous communities, technology is being used to stay connected with their people and culture. For centuries, Māori have utilised and adapted technology, and "have a long, but mostly unrecognised, history of ingenious innovation and adaptation of new technologies" (p.339) [15]. In recent times, technology has been used by Māori communities as a way to reconnect to their culture and identity digitally, and as a way to share and preserve Māori culture with projects such as Ātea [11, 24, 25, 27], advances on creating and

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virtualising Māori taonga (treasures) [10], and other projects such as Te Ao Hunga¹ and Mataatua VR². The project presented here is a demonstration on how technology can be used to introduce and educate people about an important aspect of Māori everyday life, a *pōwhiri*.

Pōwhiri is a Māori welcoming ceremony and an essential part of Māori culture, which, like all Māori elements, has its associated tikanga (protocols). The pōwhiri establishes the relationship between the mana whenua (people of the land) and the manuhiri (visitors) and allows the mana whenua to determine what the intentions of the visiting group are. The nature of the ceremony means that the associated tikanga strictly needs to be followed during the pōwhiri process. Experiencing a pōwhiri for the first time can be a confronting experience with groups singing and chanting in te reo Māori, an unfamiliar language for the majority of people living in Aotearoa New Zealand. This, alongside the rarity of pōwhiri, means that a majority of people are not in the position to fully comprehend how a pōwhiri functions and what each step in the process means. At the same time, as pōwhiri carries a significant importance for Māori and for many people living in Aotearoa New Zealand, it is likely that they will attend one at some point in their lives.

Virtualisation of tikanga is a topic that has become more and more popular in recent years. With the Māori diaspora and majority of Māori living away from their marae (communal place), many see the virtual realm as "better than nothing" [23, p.247]. Māori have a long history of technological adaptation [10, 15] and this extends to the idea of virtualising tikanga [12, 22, 26]. Physical tikanga will never be replaced by virtualised tikanga as "kanohi ki te kanohi", the face-to-face element is extremely important in Māori contexts [23]. Nevertheless, Māori are exploring how Virtual Reality (VR), and the broader technology realm, can help to address Māori diaspora issues and reconnect whānau (family) to their haukāinga (home) and their marae as well as to educate Māori and non-Māori (Pākehā) about tikanga associated with the traditional cultural practices.

Despite the research conducted in the virtualisation of tikanga and the effects of VR in learning, there is no research on the effects of VR as a learning medium for pōwhiri. Creating a VR pōwhiri experience would have the potential of opening up marae and Māori culture to an entire new group of people that may be unable to experience it otherwise. Having a system available that people can use, regardless of their location, creates the opportunity for anyone to be exposed to key parts of Māori culture and to learn about the different aspects of pōwhiri, while possibly increasing their understanding of the process by practicing pōwhiri in a controlled, safe environment. To achieve this, we developed a VR Pōwhiri system, building on top of the existing Ātea project [11, 24, 25, 27] infrastructure, that allows users to progress through the pōwhiri and be exposed to the tikanga that happens at every step. Therefore our research questions can be formulated as:

- (1) Does understanding of tikanga pōwhiri increase after using the VR Pōwhiri system?
- (2) Does confidence surrounding tikanga pōwhiri increase after using the VR Pōwhiri system?

In this paper, background and related work is provided in Section 2. This is followed by our two studies, the preliminary *Cultural Evaluation Study* in Section 3, which informed the *User Study* in Section 4. Finally, limitations, conclusion and future work are presented in Sections 5 and 6.

2 BACKGROUND AND RELATED WORK

Whereas the majority of studies show that VR increases learning gains for students [2, 4, 17, 19, 33], the consensus on the effectiveness of VR for intercultural learning is mixed with some studies reporting no significant advantage [13], while others report advantages and positive results [29, 34, 35]. Participants in the studies preferred VR as a medium for intercultural learning [34] and its potential was recognised as it allows them to navigate and feel present within the cultural context [6, 30]. VR technology has also been used to preserve Māori taonga (treasures) and culture [10] (see also the Mataatua VR project³).

2.1 Tikanga and Pōwhiri

Tikanga roughly translates to 'protocol' or 'procedure', and defines how a person should interact and behave in their daily life. It can be seen as a form of social control and when seen through this lens, "tikanga Māori controls interpersonal relationships, provides ways for groups to meet and interact, and even determines how individuals identify themselves" [20, p. 6]. Tikanga has many underlying core concepts such as whakapapa (genealogy), manaakitanga (hospitality), and tapu (sacredness) that "make us (Māori) who we are" [21, p. 24].

Pōwhiri is an integral part of Māori culture that allows the mana whenua (people of the marae) to determine the intentions of the manuhiri (visitors) and the kaupapa (agenda) of the visit, with the entire process being tapu (sacred). As pōwhiri is such a significant aspect of Māori culture there is strict tikanga around how it is conducted. Pōwhiri consists of six main steps [14] that vary depending on the tribe (iwi) conducting the ceremony. Each of these steps is highly tapu. Each step in a pōwhiri is governed by tapu, and the manuhiri are treated as being tapu. Tikanga expert Hirini Moko Mead sums this up as "The actual steps in performing a pōwhiri (eastern Māori dialect) can be viewed as the gradual reduction of tapu culminating in the eating of food which ends the ceremony" [20, p. 124].

Traditionally, manuhiri are only allowed to enter another marae if they go through the process of the pōwhiri. Preceding the ceremony, manuhiri will gather at the entrance to the marae to signal that they are preparing to start. To then initiate the pōwhiri, the manuhiri will approach the marae and start walking towards the wharenui (meeting house). The entire ceremony involves the following steps:

- (1) **Karanga (welcoming call)** is the first interaction between the mana whenua and manuhiri groups and can be seen as a conversation where the mana whenua and manuhiri give thanks to each other, honour the mate (dead) that could not be at the marae, and establish the kaupapa for the visit to the marae. Only female perform the karanga, and the

¹<https://plink.co.nz/doc/Te%20Ao%20Hunga%20-%20Overview.pdf>

²<https://www.wananga.ac.nz/experience/news/mataatua-virtual-reality-project/>

³<https://www.wananga.ac.nz/experience/news/mataatua-virtual-reality-project/>

performance of the kaikaranga (caller) can have an effect on the mana (standing) of the marae.

- (2) **Whaikōrero (speeches)** allow for the mana whenua and manuhiri to acknowledge each other and pay respect to the mate. Each marae will have their own protocol of what orders the speakers from the mana whenua and manuhiri speak. The marae itself is also seen as being part of the whaikōrero so speakers may explicitly acknowledge the marae and include it in their whaikōrero.
- (3) **Waiata (songs)** will be sung during this stage, and depending on the marae these will either happen after each speaker is finished or after each side has finished speaking.
- (4) **Koha (gift)**, the giving of a gift to the mana whenua, follows. Traditionally, the koha would have been food, supplies, or even prisoners but in contemporary times the koha is usually money to contribute to the marae. The koha is usually presented by the last speaker of the manuhiri, who will place it on the ground and then return to their seat, after which someone from the mana whenua will pick it up.
- (5) **Hongi (touching of noses)** and **harirū (handshake)** is the sharing of breath where mana whenua and manuhiri will touch noses and shake hands. Depending on the size of the pōwhiri, all of the manuhiri will perform hongis and harirū with everyone from the mana whenua, but if the groups are particularly large, only certain people will perform this. The hongis symbolises the story of how the Atua (god) of the forests, Tāne-mahuta, molded the first human from the earth and breathed life into her, creating people.
- (6) **Kai (food)** is the last step and releases the pōwhiri participants from the tapu nature of the pōwhiri and returns them to a noa (neutral) state. Noa is the balancer to tapu and by introducing it, the pōwhiri participants are free to interact with the world removed from the restrictions that tapu holds on them. To share kai, both the mana whenua and manuhiri will move to a different building in the marae complex, the wharekai (dining house), as food is not permitted on the ātea (meeting space) or in the wharehau (meeting house).

After this stage has been completed, the manuhiri have completed the pōwhiri, and do not have to undertake a pōwhiri when they visit the marae in the future as they are no longer waewae tapu (first time learners).

Virtual tikanga may act as an approximation for a lot of Māori, especially with 20% of Māori living overseas [23] and much more living outside their lands [24]. However, the practice of kanohi ki te kanohi (face to face) plays a key role in traditional tikanga [12, 23] leading to the challenge of "shifting kanohi ki te kanohi practices and rituals to the virtual space to empower their people with the ability and access to participate and engage" [23, p. iii].

Studies into the virtualisation of tikanga have mainly focused around tangihanga (funeral) tikanga [12, 22, 26], allowing dispersed whānau to participate in the ceremony. Modern technologies may allow for more and more Māori to participate in events such as tangihanga and hui (meetings) from afar in circumstances such as covid, but care must be taken when tikanga becomes virtualised with O'Carroll stating, "participants in virtual tikanga are cautioned

to tread carefully and with integrity so that the underlying principles of tikanga are respected" [22, p. 198].

2.2 Kaupapa Māori Research

Kaupapa Māori research is research conducted within a Te Ao Māori viewpoint where Māori values and principles are at the forefront of the research. There are many elements that make up kaupapa Māori research, but the main element is tino rangatiratanga, which is the idea of sovereignty [32]. For our research this means that the Māori community involved representing Te Rau Aroha marae have the final say over what happens with the provided outcomes and guide us at important stages of the project. An example of research into virtualisation of tikanga following the kaupapa Māori research framework described in O'Carroll's paper: *Virtual Tangihanga, Virtual Tikanga: Investigating the potential and pitfalls of virtualising Māori cultural practices and rituals* [22]. To undertake her research, O'Carroll approached the research from her Te Ao Māori worldview that she was brought up in; "the framework (of the research) is informed by my tribal upbringing, which contributes greatly to the way I interpret and make meaning." [22, p.189]. The research explores how tikanga has adapted as it has been virtualised, with interviews and focus groups conducted with iwi (tribe) members and kaumātua (elders) to explore how the virtualisation of tikanga may impact Māori, encompassing the social justice aspect of kaupapa Māori research.

In other words, kaupapa Māori research helps to frame critical questions arising from undertaking research within indigenous communities including: who owns the research? who will benefit from the research? and whose interests does the research serve? [31]. By following the key principles of kaupapa Māori research outlined above, we can provide outcomes that fit within this Te Ao Māori worldview.

Our mixed team of two pākeha and two Māori researchers continuously reflected on kaupapa Māori. Through the last author's affiliation with Te Rau Aroha marae and his tribal roots with Ngāi Tahu we have been in ongoing contact with the appropriate Te Ao and Tikanga experts. The first author, who is of Tūhoe descent, took care not to impose their tikanga on the research and regularly paused to reflect on how Te Rau Aroha tikanga was portrayed in the research.

2.3 Ātea Project

The Ātea project⁴ is an example of kaupapa Māori research and provided the foundation for the VR Pōwhiri project. The Ātea project is conducted in collaboration with Te Rau Aroha marae in Bluff with the aim to provide an immersive VR experience which enables mana whenua of Te Rau Aroha marae to be present within their wharehau with others, such as whānau or kaumātua in real time. VR is used to preserve and share the history, culture and language [24], while also allowing users to reconnect with their culture. To do this, the project faithfully recreates the interior of the wharehau. This recreation of the interior accurately depicts the carvings and tipuna (ancestral) figures held within the wharehau to create a sense of "being there" for the user when they are in the virtual wharehau [27].

⁴<https://www.sftichallenge.govt.nz/our-research/projects/spearhead/atea/>

Users are represented as voxels, volumetric pixels, and are able to see parts of their own body and others who are in the virtual environment with them. At the same time users are able to listen to recorded kaumātua, also represented as voxels, telling the stories while referring to the carvings and artwork on the walls of the marae with the aim to preserve and share their knowledge especially with the next generation [27].

By recording the kaumātua and integrating the voxel recordings (3D videos) into the wharenui, the Ātea project has the potential to keep the tradition of oral knowledge transfer alive [25] within a modern technological context. These voxel video recordings allow iwi and whānau members to learn their culture and traditions through the stories of their kaumātua while educating others not from Te Rau Aroha on the history of the marae and of Ngāi Tahu, the iwi of the area. Figure 2 shows the Ātea telepresence system.



Figure 2: Ātea storytelling system with visitors listening to a kaumātua describing the stories of the marae.

The Ātea project system is built in Unreal Engine⁵ allowing for a rich wharenui model to be explored while making use of spatial audio rendering [11]. The model was created using photogrammetry techniques where thousands of photos are stitched together using a computer program to create a 3D model of the wharenui interior [27]. Included within the wharenui are 3D reconstructions created using voxels, recorded in a streaming fashion resulting in videos, that depict kaumātua of the marae. To record, implement, and playback these videos in real-time, a plugin called VIMR (voxel-based immersive mixed reality) was developed [11]. By having voxel video representations of these actors, the sense of presence (being there) and sense of co-presence (being there together with someone else) for users of the Ātea system has been reported to be supported [27].

The VR Pōwhiri system is an extension of the system described above. With this research we add in a culturally correct way to enter a wharenui along with implementing a way for users to gain understanding and confidence surrounding the pōwhiri process that was previously not part of the system. We made use of the voxel functionality and the existing model of the wharenui interior, while extending the virtual environment. As the pōwhiri process starts at the gate to the marae complex, photogrammetry techniques

where used by the Ātea team to also create the exterior of Te Rau Aroha marae and the surrounding environment. This included the path leading towards the wharenui entrance as well as the gate and other structures such as the pou (columns) and the carved maihi (arches) above the wharenui door. Additionally, voxel videos of actors performing the key parts of a pōwhiri were recorded so that users would be able to observe how pōwhiri at Te Rau Aroha marae would be performed between different pōwhiri participants.

3 CULTURAL EVALUATION STUDY

Using the first iteration of the developed VR Pōwhiri system a *Cultural Evaluation Study* was conducted to obtain feedback about the cultural suitability of the system. The cultural evaluation study was a user study with experts in tikanga pōwhiri and to distinguish its aim of cultural correctness from our later user study we came up with the name *Cultural Evaluation Study*, with the main focus being cultural feedback rather than technological feedback. To gather this feedback, we designed the study so that we could obtain real-time feedback on the cultural elements of pōwhiri, by having participants pause at certain places in the system and answer during exposure questions about the tikanga they had just experienced.

To control how participants progressed through the study, invisible walls were placed on the path to block progress at points determined prior by Te Rau Aroha marae mana whenua. To activate certain tikanga pōwhiri steps, trigger boxes were utilised that activated 3D video reconstructions of actors for the participants to watch when they entered the bounds of the trigger box. Lastly, trigger boxes were also used to activate narrations in the system that explained to the participants what was about to happen and the significance behind each tikanga step.

After the system use, a post-exposure interview was scheduled allowing us to ask questions regarding the correctness of the tikanga portrayed, common mistakes observed during marae visits and to trigger any cultural feedback as well as to ascertain participants' views on VR as a medium for cultural learning.

The two guiding questions for this study can be summarised as:

- (1) Is the tikanga and tapu of the pōwhiri conveyed correctly?
- (2) What are common pōwhiri mistakes we would need to address in a VR Pōwhiri?

The *Cultural Evaluation Study* was conducted during a visit to Te Rau Aroha marae and all participants were recruited during this visit. In total, we had six participants with knowledge of different areas of pōwhiri and Te Ao Māori. Of these participants, four were male and two were female, aged between 35 and over 65. Three participants were mana whenua that perform tasks such as whaikōrero and koha. Two participants were kaikaranga, with one being mana whenua and one being manuhiri.

Ethical approval was obtained through the University of Otago ethics committee. This included audio recordings of participants' answers during progression questions and the post-exposure interview. Additionally, thanks to a pre-existing relationship, Te Rau Aroha marae approved the conducting of the study at the marae with mana whenua members.

From the recorded responses, we loosely followed a thematic analysis approach [8] to determine themes. This was done by listening to the interview audio and collating the key themes, along

⁵<https://www.unrealengine.com/en-US>

with correlating quotations, into respective documents. Once all of the interviews had gone through this process, we collated them into a single document that summarised the key themes arising from all interviews. Following this process allowed us to determine the key themes of what knowledgeable Māori and mana whenua determined as the most important aspects. These key themes were identified as 'narrations', 'tikanga and voxel videos', 'common mistakes', and a category of 'other feedback' which we determined as important for further VR Pōwhiri implementations. After transcribing the interviews and determining important themes, the audio was destroyed in accordance with the university's ethics guidelines. Due to the main researcher's inexperience in conducting qualitative research, key themes were noted down from participants but there was a lack of foresight to note down direct quotes from participants, with only a small number collected.

3.1 Task and Questions

A PC and monitor was set up on a table with the participants sitting in a chair facing the monitor. The monitor allowed the administrator to observe what the participant was seeing in VR. The participant would interact with the system using a VR headset. To progress through the system, the participants used a trigger walking system [28]. Participants press the trigger on the VR controller and move forward a small amount on each trigger release. This way the slow deliberate walk towards the wharenui present in real life pōwhiri could be simulated. Trigger walking allowed the participants to navigate in the direction of their gaze and to progress along the path and enter the wharenui as shown in Figure 4.

At certain points in the procedure the participants had to stop to answer questions asked by the experimenter. During each stage of the pōwhiri process, participants would experience the relevant tikanga through voxel video reconstructions of pōwhiri actors.

At the four stop points (see Figure 4) participants were asked questions as we wanted to obtain feedback at points in the pōwhiri where mana whenua had indicated manuhiri should stop. Asking questions at these stop points, as outlined in Figure 3, allowed us to gather real time feedback on the cultural correctness of the system at key stages in a pōwhiri. These questions were derived from our motivation to ensure the tikanga portrayed at each key stage of the pōwhiri is accurate to Te Rau Aroha. Pōwhiri has different tikanga depending on the iwi and what the main author who is of Tūhoe descent may think of as 'normal' tikanga will be different at Te Rau Aroha.

After the participants had progressed through the system, they took part in a post-exposure semi-structured interview exploring the effectiveness of the VR Pōwhiri system at conveying the tikanga pōwhiri and common mistakes. The resulting discussions allowed the participant and researcher to elaborate on the answers given during the progression stages and allowed the participant to 'vocalise' their experience regarding the virtual tikanga they had just experienced. Additionally, questions were asked about the participants' thoughts on VR for cultural learning, sense of presence and enjoyment, and whether they had concerns about any part of the VR Pōwhiri system. These questions were motivated by our desire to understand the thoughts of mana whenua and Māori who are knowledgeable in tikanga surrounding pōwhiri, in regards to using

VR as a way to preserve their culture. Additionally, we wanted to understand whether the users felt present in the space, as if they were actually at Te Rau Aroha marae, whether they enjoyed their experience, and their reasons behind their answers.

Stage	Questions
Participant reaches 1 st stop point	<ul style="list-style-type: none"> Where are you? What do you see? What do you expect to happen next? What should happen next?
Progress through stop point 1 to stop point 2	
Voxel videos play during progression	<ul style="list-style-type: none"> Does this step always happen here? Is this local to your marae or more general? How many people should be present at these steps?
Participant reaches 2 nd stop point	<ul style="list-style-type: none"> How well were the steps you just experienced portrayed? Should anything else happen between these two stop points? What are common mistakes people make at this stage? What are some common mistakes at this point? How severe are these mistakes? Any more feedback?
Participant is then asked about what they expect to happen between stop point 2 and 3	<ul style="list-style-type: none"> Where are you? What do you see? What do you expect to happen next? What should happen next?
Progress through stop point 2 to stop point 3	

Figure 3: Questions that participants were asked as they progressed through the VR Pōwhiri. These questions were repeated at each of the four defined stop points.

3.2 Results

With their combined knowledge of tikanga pōwhiri and Te Ao Māori, participants were able to highlight the complexity of the cultural elements as well as to provide very valuable feedback on the following aspects of the system:

3.2.1 Narrations. Pre-recorded narrations, typically between one and two minutes, are a key aspect in the VR Pōwhiri system and are started by the participant reaching a certain stage in the VR Pōwhiri. These narrations explain what is happening at each step in the pōwhiri, why it is happening, and what it represents. In total, there were five narrations for participants to listen to as shown in Figure 4.

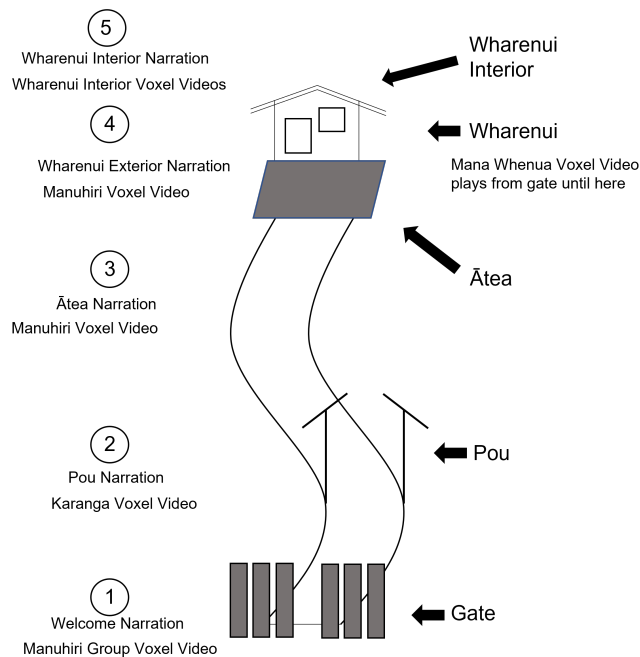


Figure 4: Key points in pōwhiri progression indicating where narrations and voxel videos play.

As the participants were knowledgeable, the feedback focused around what could be adjusted in the narration content and which aspects in the narrations were missing. It was suggested to mention that a) it is expected of the manuhiri as they wait at the entrance gate to Te Rau Aroha marae to decide who in the group will be performing the karanga, whaikōrero, and koha and b) that it is also expected that women will lead the men and support the kaikaranga when progressing up the path. This was highlighted by one participant who noted that this is "to support the kaikaranga, to protect her", as "in the karanga you are talking to the spirit world you want her (the caller) to be protected during that".

In regards to tikanga, more emphasis on the role that Atua (gods) play in tikanga pōwhiri was requested, specifically Tūmatauenga and Rongo-mā-Tāne, and how they contribute to the tapu nature of a pōwhiri. Tūmatauenga is the god of war and humankind, whose realm you are in when you are on the ātea. Rongo-mā-Tāne is the god of peace, and when you enter the wharenui, you are in his realm. Additionally, any mentions of being free to explore the space need to be removed, with one participant noting this is because "once the karanga starts, you're [the participant] in the realm of Tūmatauenga" and people need to navigate the space according to these guidelines in order to be safe. While participants liked the mention of Te Rau Aroha unique styling in these narrations, some changes were suggested, especially regarding the three maihi (arches) at the entrance. As described by one mana whenua participant, these maihi are "representing the three tribes, the three mountains and the three waka with the carved tūpuna at the top", and are integral to the identity of mana whenua at Te Rau Aroha marae.

The narration for the interior steps was too long and should to be broken up into smaller pieces of information. Reference to the tikanga style of Te Rau Aroha needs to be made as one participant remarked "The kawa of this marae is Paeke" which means that when the whaikōrero are happening, all mana whenua speakers complete their whaikōrero before the manuhiri speakers start. In contrast, "Tau Ututu" is a different form where mana whenua and manuhiri speakers alternate until they are all finished. As the pōwhiri steps happening inside are different compared to other marae, one participant noted that "this is our tikanga, learn it, know it", and acknowledged that the narrations can help with gaining this understanding.

3.2.2 Voxel Videos. The tikanga pōwhiri was conveyed using pre-recorded voxel videos allowing participants to watch the tikanga being performed and provide feedback at different stages in the system as shown in Figure 4:

One major aspect of necessary improvement to be made was regarding the pace, speed, and timing of the voxel videos with respect to the general pace of approaching the ātea space, the speed of the voxel videos themselves, and the synchronization with the events happening. A lack of movement from the mana whenua kaikaranga and the karanga stopping when the participant reaches the ātea space were highlighted as other major tikanga issues surrounding the karanga.

While the overall appearance of the VR Pōwhiri system was judged to be appropriate, it was stressed that the mana whenua and manuhiri characters have to be dressed formally and that they have to behave in a tikanga-observant way, e.g. when communicating with each other. Also, the seating procedures for both parties have to be adhered to (rows of seats left and right) as well as the different ways and locations of how koha and kai are shared.

3.2.3 Common Mistakes. During the interviews the participants mentioned the following common mistakes and suggested to educate manuhiri on how to avoid these pitfalls.

Due to the unique layout of Te Rau Aroha, manuhiri may wait down at the main entrance gate expecting the karanga to start but are in fact meant to walk forward towards the two pou to indicate that they are ready to start the karanga. Therefore, mana whenua may need to come down the path and explain to manuhiri how to initiate the pōwhiri and how they should form their group. Manuhiri need to make sure that women are walking at the front of the group with men following, and that the group stays compact as they walk up to the wharenui.

As they walk towards the wharenui, manuhiri also need to make sure that they do not move in front of the kaikaranga and distract her as she calls. It is important that the manuhiri keep this pace so that the kaikaranga does not have to repeat anything in her call. For the kaikaranga herself, she will stop and start during the walk to the wharenui and the manuhiri should follow this lead. There will be a stop at the entrance to the ātea space to allow for a reflection of those who have passed and the mate (dead) that have been bought along with the living to the pōwhiri. This is a key step in the pōwhiri that manuhiri should be careful not to ignore or dismiss.

When the manuhiri reach the wharenui, they may also make the mistake of not understanding the seating arrangement. Men

always sit at the front of the group for the whaikōrero, waiata, koha, and hongi and harirū. The manuhiri will have designated speakers and not all men sitting in the front will have to whaikōrero. Reading the speech from paper will diminish the mana (standing) of both the speaker and the mana whenua and the same goes for the kaikaranga if she has to constantly look down and read the lines as she is performing the karanga. As these steps are important aspects of pōwhiri, children need to be controlled and should not be distracting to the kaikōrero.

3.3 System Adaptation

Regarding the narrations, the majority of mana whenua were satisfied but noted that tweaks were needed. These included content that needs to be added or removed, breaks in the narration audio, and edits to the length of the audio. Feedback on the narrations from the *Cultural Evaluation Study* was used to update these for the next iteration of the VR Pōwhiri, with mana whenua and kaikaranga participants both indicating that they would volunteer to be the voice of the narrations at their respective pōwhiri steps.

Voxel videos were also a major source of feedback from participants. This feedback included the need to adjust the pace of the walking video to match the length of the karanga, where the karanga stops and how the voxel videos in the wharenui interior were portrayed. The interior portrayal feedback was addressed by creating a pōwhiri scene in the wharenui interior that accurately reflected how a real pōwhiri would be staged. For the karanga feedback, we addressed this by timing the voxel videos to audio of real kaikaranga performing the karanga and continuing the audio after the pause at the ātea.

Common mistakes to focus on in the system included manuhiri not understanding how to initiate the pōwhiri process, how to progress towards the wharenui with the kaikaranga, and where to sit during the stages in the wharenui interior. To help alleviate these mistakes and educate the users, we included updated narrations that explained to users what is expected of them and how to behave at these stages in the process.

4 USER STUDY

After implementing the feedback from the *Cultural Evaluation Study*, we conducted a user study to address our research questions in regards to the increase in understanding and confidence surrounding pōwhiri. This study also provided us with a chance to learn about users' sense of presence and the usability of the system.

The *User Study* was conducted in an unused room in the department. The room consisted of two desks, one where participants would complete the quizzes and questionnaires, and one where the administrator would be able to watch what the participant is doing inside the virtual environment. Unlike the *Cultural Evaluation Study*, participants would stand after they had put on the HMD (Head Mounted Display) and complete a pōwhiri, but at the last step in the process when taking their place in the wharenui they were told to sit back down, with someone positioning a chair for them to sit on while wearing the HMD.

Participants were recruited using the researchers Māori connections, flyers hung throughout the university, outreach through university lecturers, and recommendations from peers conducting

their own user studies. From all of this, we recruited 21 participants for the user study. Seventeen of the participants were waewae tapu and had little to no knowledge of tikanga pōwhiri, these are first time learners of the pōwhiri process and can be of any cultural background. The remaining four participants were Māori who were knowledgeable of tikanga pōwhiri that would be asked questions about the portrayal of tikanga in the VR Pōwhiri. A sample size of 21 is comparable to similar studies in the HCI field for expected strong effects.

Ethical approval for the study was obtained through the University of Otago ethics committee. This included obtaining participant demographics, along with audio recordings of participants' answers to the post-exposure interview. These audio recordings were then destroyed after transcription and pseudonymisation.



Figure 5: Updated wharenui interior showing the scene and activated voxel videos participants saw when they were asked to sit.

4.1 Task, Quiz, and Questionnaires

For the *User Study*, participants were tasked with completing a pōwhiri in the updated VR Pōwhiri system. Unlike the system for the *Cultural Evaluation Study*, the updated system did not have any stop points and participants could progress through the pōwhiri process without any hindrances. Instead, as they progressed, the administrator could talk to the participant in the VR Pōwhiri system using a microphone and instruct them on what to do if necessary. Participants experienced the updated tikanga pōwhiri through voxel video reconstructions of pōwhiri actors, however this time the system incorporated authentic Te Rau Aroha karanga and whaikōrero from kaikaranga and kaikōrero. Once they reached the wharenui interior, participants were instructed to sit as they would in real life to experience this section of tikanga pōwhiri. After the pōwhiri process had finished, participants were welcome to explore their surroundings for as long as they wished.

Participants had an open space where they could be tracked by the HMD and were allowed to physically walk in. This open space allowed for the apparatus to be as minimally noticeable and for the participant to progress through the system using a VR headset and controller. The participants used the same trigger walking technique [28] as before.

Before using the system, participants completed a quiz to establish a baseline of their understanding and confidence surrounding

pōwhiri. They then completed the same quiz after the use of the system allowing us to determine any changes in their understanding and confidence. If a participant was one of the four knowledgeable Māori, they skipped the pre- and post-exposure quizzes as we did not expect any changes in understanding or confidence.

Participants from all groups were then asked to complete four further questionnaires, namely the Igroup Presence Questionnaire (IPQ)⁶, Bailenson Co-Presence Questionnaire [3], the System Usability Scale (SUS) [9], and the Simulator Sickness Questionnaire (SSQ) [16], which are described later.

As the last step, participants took part in a short semi-structured interview. These interviews allowed us to elaborate on any changes in understanding and confidence, their sense of presence and co-presence, and the usability of the system. Knowledgeable participants were asked about the correctness of the portrayal of tikanga and their thoughts on tikanga virtualisation.

4.2 Procedure and Data Collection

After arrival, participants were asked to read the information sheet and complete the consent form, along with a demographics form and to complete a pre-exposure quiz. After completing the quiz, participants were instructed how to navigate and information was provided how to use the system. Finally, the HMD was fitted and they could start when they were ready. After use of the system, participants then completed the same quiz again, along with further questionnaires and a post-study semi-structured interview as described previously.

The quiz was analysed in two parts: the understanding questions and the confidence statements. For the understanding questions, we counted how many participants supplied a correct answer before and after the system use. For the confidence statements, a paired *t-test* was performed and *Cohens d* effect size was calculated. The questionnaires were administered according to the procedures established in the literature, such as the IPQ using an online tool and the SUS using a system of summing scores together. Lastly, to analyse the interviews, we again followed loosely a thematic analysis to establish common themes.

4.3 Results

First, the results from the pre- and post-exposure quiz are presented, followed by the IPQ, the Bailenson Co-Presence Questionnaire, the SUS, the SSQ, and finally the post-exposure semi-structured interview. As a general observation, participants mostly enjoyed using the system and provided valuable feedback on various aspects which will be discussed at the end of his section.

4.3.1 Pre and Post-Exposure Quiz. In total, 17 participants completed the pre- and post-exposure quiz as the four knowledgeable Māori participants already had understanding and confidence surrounding tikanga pōwhiri and the quiz would have been meaningless given their expertise in tikanga pōwhiri. Alongside with answering each of the three multiple choice questions and the mapping exercise, participants were asked to indicate their confidence in their chosen answer. We first report on the data from the understanding questions relating to tikanga pōwhiri:

Q1: What is a pōwhiri?

Q2: Which are valid elements of a pōwhiri?

Q3: Who takes part in a pōwhiri?

Q4: Please indicate the location for the listed activities by drawing arrows to points on the map.

Once participants had completed the first three questions they were presented with the mapping exercise (Q4) as this item included correct answers for Q2. Q1 and Q3 were scored using 1 = Correct and 0 = Incorrect. As Q1 and Q3 were multiple choice, 0.5 was scored if a participant got the answer correct but also chose an incorrect answer.

Q1 (What is a pōwhiri?): Pre-exposure, 8 participants answered correctly ($M = 0.47$, $SD = 0.51$) and post-exposure this increased to 13, with an increase post-exposure ($M = 0.76$, $SD = 0.44$). This shows a gain of five participants being able to correctly identify what a pōwhiri is, after using the system.

Q2 (Which are valid elements of a pōwhiri?): Here participants were asked to indicate from a list, which activities were part of a pōwhiri, with 6 correct activities in the list resulting in a maximum of 6 points to be scored. The majority of participants (11 out of 17) scored between zero and two pre-exposure ($M = 1.82$, $SD = 2.04$). This increased to almost everybody (15 out of 17) scoring between five and six ($M = 5.12$, $SD = 1.32$) indicating an increase in understanding post-exposure.

Q3 (Who takes part in a pōwhiri?): Pre-exposure, four participants answered correctly, and two participants selected a correct answer along with an incorrect answer ($M = 0.29$, $SD = 0.44$). Post-exposure this increased to seven participants answering correctly, with two still selecting a correct answer along with an incorrect one ($M = 0.47$, $SD = 0.48$). This shows an increase of three participants who could correctly indicate who takes part in a pōwhiri post-exposure.

Q4 (Please indicate the location for the listed activities by drawing arrows to points on the map.): Participants were asked to indicate where the activities take place. Six steps had to be mapped correctly to score all six points. The majority of participants (12 out of 17) scored between two and four points pre-exposure ($M = 2.53$, $SD = 1.58$). This increased to the majority of participants (16 out of 17) scoring between four and six correct post-exposure ($M = 5.12$, $SD = 0.93$). This again highlights the increase in understanding about the steps of the pōwhiri and their correct order.

Q1 to Q4 (Confidence in answer): Along with answering the four understanding questions, participants also indicated their confidence in their chosen answers for each question on a scale of 1 = Very Confident, 6 = Not Very Confident (values reversed for analysis). Paired *t-tests* were performed using the pre- and post-exposure confidence values of each question separately (see Table 1).

We can observe a significant ($p < 0.01$) increase in participants' confidence regarding their answers to Q1 to Q4 after they have been using the system. This is also evident from large effect sizes of *Cohens d*: 1.44 to 2.17.

4.3.2 Pre- and Post-Exposure Confidence Statements. One of the pre- and post-exposure quizzes aims was to determine if confidence in attending a real pōwhiri increases through the use of the VR Pōwhiri system. We asked participants to rate the following statements, with (r) denoting reverse coded items:

⁶<http://www.igroup.org/pq/ipq/download.php>

Table 1: Participants' confidence in Q1-Q4 answers pre- and post-exposure.

Participants' Confidence in answering Q1 to Q4				
Item	Pre Mean, SD	Post Mean, SD	Cohens d	P-value
Q1	M = 2.35, SD = 1.66	M = 4.71, SD = 1.26	1.60	p < 0.01
Q2	M = 2.18, SD = 1.47	M = 4.76, SD = 1.15	1.95	p < 0.01
Q3	M = 1.88, SD = 1.32	M = 3.71, SD = 1.21	1.44	p < 0.01
Q4	M = 2.00, SD = 1.12	M = 4.29, SD = 0.99	2.17	p < 0.01

S1: I have a clear idea of what a Pōwhiri is.

S2: I can confidently explain all steps that are involved.

S3: If I were invited to attend a Pōwhiri tomorrow, I would feel confident.

S4: I would always know what to do next.

S5: I would be nervous to attend a Pōwhiri tomorrow. (r)

S6: If attending a Pōwhiri tomorrow, I would need to watch others to know what to do. (r)

S7: I would always know my place in the group during Pōwhiri.

For these statements, the participants indicated values between 1 = Strongly Agree and 6 = Strongly Disagree (values reversed for analysis) for each statement. Based on this scoring, an average score closer to 6 indicates high confidence and an average score closer to 1 indicates low confidence, with a midpoint of 3.5. The results from these questions are shown in Table 2.

Table 2: Participants' confidence to attend a pōwhiri

Participants' S1-S7 Confidence				
Item	Pre Mean, SD	Post Mean, SD	Cohens d	P-value
S1	M = 2.00, SD = 1.27	M = 4.65, SD = 0.93	2.38	p < 0.01
S2	M = 1.47, SD = 1.01	M = 3.65, SD = 0.86	2.32	p < 0.01
S3	M = 1.71, SD = 1.10	M = 3.94, SD = 0.97	2.15	p < 0.01
S4	M = 1.47, SD = 0.94	M = 3.53, SD = 1.12	1.99	p < 0.01
S5	M = 2.59, SD = 1.84	M = 3.29, SD = 1.65	0.40	p = 0.39
S6	M = 1.29, SD = 0.69	M = 4.53, SD = 1.23	3.24	p < 0.01
S7	M = 1.82, SD = 1.38	M = 4.29, SD = 0.92	2.01	p < 0.01

Cronbach's Alpha was calculated with 0.91 demonstrating high internal consistency by showing that the confidence statements strongly relate to the same concept. We do however need to acknowledge that the sample pool was small (n = 17), and that this high score may be attributed to some of the statements being too similar to each other.

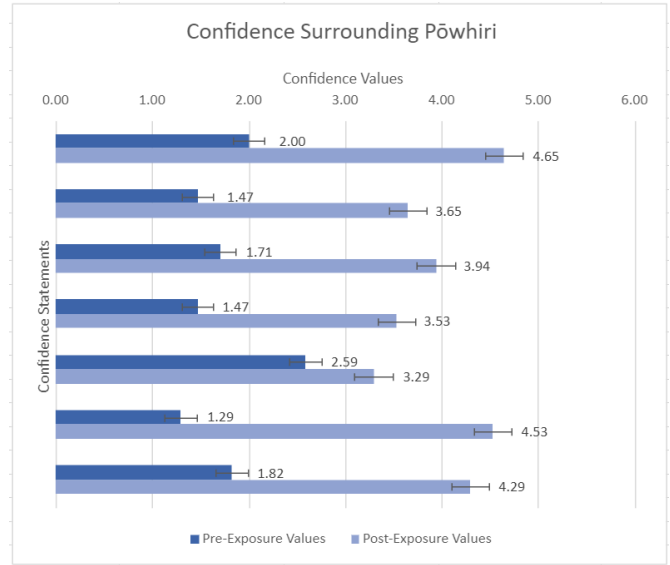
**Figure 6: Chart indicating participants' confidence surrounding pōwhiri (larger values indicate higher confidence)**

Figure 6 shows that participants' confidence in attending a pōwhiri and performing the necessary steps increased. Highest gains can be observed for S6 (If attending a Pōwhiri tomorrow, I would need to watch others to know what to do), S7 (I would always know my place in the group during Pōwhiri), and S1 (I have a clear idea of what a Pōwhiri is).

Paired *t*-tests (Table 2) showed that the differences observed are significant (p < 0.01), with the exception of S5 (I would be nervous to attend a Pōwhiri tomorrow). In fact, it is also the only item where the mean is still below the midpoint of 3.5 post-exposure, indicating that participants are nervous regardless of using the VR Pōwhiri system. We may conclude that the VR Pōwhiri system is not as effective at helping participants with feelings of nervousness as it is with increasing understanding and confidence.

In summary, the *User Study* system increased participants' confidence in attending a pōwhiri and their understanding, but could not dissolve the feeling of nervousness surrounding pōwhiri to the same degree.

4.3.3 Questionnaires. Four different questionnaires were administered after use of the VR Pōwhiri system, namely:

Presence (IPQ): The IPQ data submitted to the online IPCal⁷ tool. This tool compares our results with results from 198 other user studies, returning a result determining how present participants felt in our user study compared to these other user studies. The average score of the IPQ was 0.71 with a standard deviation of 0.58 indicating a high average sense of presence. There was however, one outlier who had a low overall sense of presence in the virtual marae environment, which was not removed.

Co-Presence (Bailenson): The average of co-presence ratings was 3.16 (SD = 0.88; range 1-6 against a scale midpoint of 3.5), indicating that the feeling of co-presence was not as strong as

⁷<https://www.hci.otago.ac.nz/ipqcal/>

for presence. We expected the co-presence scores to be low since the 'others' in the system are not real people to interact with, but recorded voxel videos of people.

System Usability Scale (SUS): The average SUS score was 80.12, with a maximum score of 97.5, minimum 37.5, and a standard deviation of 13.95. an average of 80.12 is seen as an "A" grade for the SUS [18]. Compared to other studies [5], an average of 80 is a higher score than the overall mean average of 70.14 and median average of 75, indicating a perceived high usability of the *User Study* system.

Simulator Sickness Questionnaire (SSQ): To assess the SSQ, each participants' scores were summed. Following other papers [1, 7], the SSQ was divided into three subscales, these being nausea (N), oculomotor disturbance (O), and disorientation (D). A sum was obtained for each subscale from each participant, along with a total sum (T). Following a scoring scale of < 5 being negligible, 5-10 being minimal, 10-15 being significant, and 15-20 being concerning [7], we were able to determine that a majority of participants in the VR Pōwhiri system did not experience significant simulator sickness symptoms. Five participants did feel significant or greater simulator sickness symptoms, and this is a concern for us, in particular one participant who scored above 20. This highlights a significant issue with the system.

4.3.4 Post-Exposure Interview. During the interview, 17 participants were asked about their understanding and confidence, and all 21 participants were asked about enjoyability and usability, sense of presence and co-presence, and improvements to the VR Pōwhiri post-exposure. The four knowledgeable participants were asked additional questions regarding the portrayal of tikanga in the VR Pōwhiri and their thoughts on virtualisation of tikanga. Although the researcher had previously conducted the cultural evaluation study, their inexperience showed in the lack of foresight in transcribing more direct quotes from participants.

Understanding and Confidence: All 17 participants indicated that their understanding increased, with the main reason being the feeling of a sense of progression and a feeling of participating in a pōwhiri. One participant notes that "it was more an interactive experience [rather] than watching a video", and another participant mentioned that in particular progressing through the space was integral to their experience: "physically moving through the space was really awesome". Furthermore, the fact participants could look around the environment, which helped with their increase in understanding, was also noted.

However, five participants struggled with the amount of information given at a particular time and one said: "I thought all the new information coming [in], sometimes felt overwhelming". This is not surprising as participants are brought into a large colourful marae scene with bird sounds playing in the background, along with narrations and voxel videos.

Similar to understanding, all participants felt an increase in confidence to different degrees. One participant noted that it was "actually kind of almost [like] living one". Similarly, another participant noted "I think for me it's being able to experience it ... being able to feel and see that you [are] being part of the process", highlighting that perceived sense of presence played a significant role in participants confidence increase surrounding tikanga pōwhiri.

Enjoyability: Te Rau Aroha marae is unique in both its exterior and interior styling, and 20 out of 21 participants indicated that they found the VR Pōwhiri enjoyable to use mainly because of this. One participant commented that "the marae that was chosen, what a beautiful marae. I think that was a great part of the experience", while another participant stated that they "really enjoyed walking into the marae".

In contrast, the resolution of voxel video representations was seen as an aspect for improvement, along with the fact that the headset was not the most comfortable, especially when wearing glasses. Regarding the quality of the voxel videos and the fact that participants could move through them one participant remarked: "better quality, because some of the pictures [are] see-through as we're walking up".

Usability: All participants found the VR Pōwhiri easy to use due to the implemented control scheme and the explanation given pre-exposure. However, improvements were also discussed, mainly around the navigation system of the VR Pōwhiri. It was suggested to change the control of direction from gaze to where the VR controller is pointing. Looking in the direction to move was noted by one participant as limiting the experience: "since you had to go forward, where you're looking at, you don't really get to look around as much".

Presence: 20 out of 21 participants indicated that they felt present in the virtual marae environment. Participants indicated that the environment played a key role in their sense of presence and that they "felt that I'm walking into the marae", another participant noted that they still felt that they had to "behave in a certain way that, I couldn't just relax. I had to check that I'm not walking too fast, because then I would break the rule that I have to walk behind the woman", highlighting that participants felt the tikanga pōwhiri was also important in the virtual world.

However, there were elements that reminded participants that they were anchored in the real world such as the voxel video quality and lack of a more dynamic environment. They would have liked the environment to feel more 'alive'. A suggestion for this was to include "the birds chirping ... if it's near the water, then having the waves crashing". Such ambient noises would potentially allow the participants to feel more present in the virtual environment.

Co-Presence: Not all participants felt co-present in the VR Pōwhiri due to a variety of factors such as being unable to interact with the voxel videos. For participants who felt co-present, the main factor was that they followed what the group was doing, and modelled their own behaviour in the virtual environment on the group voxel video. This was highlighted by one participant who said they "checked what they [the group] are doing and try to adapt like in the real world".

Participants indicated that they would feel more co-present with the group if they were more involved in the pōwhiri by actually interactively performing these steps with the others. One suggestion was to have the group voxel video to introduce themselves before the user progresses through the pōwhiri. Another way to improve the sense of co-presence, might be if multiple participants could interact in real time with each other by using the Ātea system's telepresence component [24].

System Improvements: The resolution of the voxel videos was a major aspect for potential improvements. One participant remarked

that the voxel video representations resembled "minecraft people" which was regarded as a distraction. Another improvement was the separation between the male and female group members as female participants found it difficult to position themselves between the men and women in the group of voxel characters.

When in the wharenui, participants were told to sit as they would in a real life pōwhiri. When sitting down, participants noted that they had to look over their shoulder to watch the videos and this caused some discomfort. This could be resolved by indicating to the participants where to sit when they enter the wharenui.

Narrations were mentioned by seven participants, in particular the ability to rewind and replay the information. This would also help to address earlier feedback about the amount of information being overwhelming and allow participants to control better the flow of information. Another suggestion was to have a visual indicator to help to identify who is speaking at the different stages such as karanga and whaikōrero.

Other improvements mentioned were the trigger walking to be increased to a larger distance, the audio timings on the voxel videos and the audio quality as we were only able to obtain phone recordings of kaikaranga and kaikōrero.

Portrayal of Tikanga: The four knowledgeable participants confirmed that the tikanga of the pōwhiri was correct but as none of those four participants were of Ngāi Tahu descent or whakapapa to Te Rau Aroha marae, it was emphasised that the tikanga of the pōwhiri was only correct to the Te Rau Aroha marae context (as compared to their home marae). Therefore these participants would have liked a greater emphasis on these differences and more explanations of the "why"; why each pōwhiri step is done and its role in the relationship between tapu and noa along with emphasis that the steps portrayed are only generic pōwhiri steps and do not represent all possible steps in a pōwhiri.

The main improvement suggested was to include the kai step of a pōwhiri as highlighted by one participant who said "it'd be cool to include going for a kai or maybe explaining the importance of why you need to do that, so you can go into the noa." Currently this step is not portrayed in the VR Pōwhiri as the wharekai (dining hall) at Te Rau Aroha is not modeled and as it is difficult to simulate because of the other senses, such as taste, being involved.

All knowledgeable participants were receptive to the idea of tikanga virtualisation, but stressed that a virtual replication of a Māori ritual is not a replacement to the physical tikanga, instead, a tool to allow people to learn how tikanga pōwhiri works. One participant did note, however, that virtualisation of tikanga could play a role in maintaining tikanga, saying that "because times change, and keeping tikanga is important ... so especially through COVID, it was needed". This highlights the potential that virtualisation of tikanga could help in keeping Māori connected to their traditions while being separated physically.

4.4 Summary

From the *User Study* quiz and questionnaire findings, we can see that the VR Pōwhiri had a positive effect on users' understanding and confidence. Each of the four understanding questions saw an increase in correct answers post-exposure and a significant increase

in users' confidence when answering these questions. Additionally, six of the seven confidence statements showed a significant increase in confidence post-exposure, with only one exception, the nervousness.

The interviews revealed that the main reason for understanding and confidence gain was the participants' feeling of taking part in a pōwhiri as opposed to observing one. This was highlighted by multiple participants as a major factor in their gains and is a key aspect of the VR Pōwhiri. Additionally, this correlates with participants' high sense of presence in the system, as reflected in the IPQ data. The sense of co-presence was not as high as presence and participants suggested improvements to help with this, such as being able to interact with the voxel videos.

Participants found the system easy to use and enjoyable. Only one button of the controller is needed to navigate the system, and this, along with the slow pace, was highlighted as a reason for the ease of use. One participant however did not find the system enjoyable to use and struggled with the hardware and the amount of information provided as too many elements were occurring at the same time. The latter issue was also commented on by other participants and needs to be investigated. Another aspect impacting the enjoyability negatively was the quality of the voxel videos.

Improving the quality of the voxel videos was not only a suggestion for usability and enjoyment, but also for presence, co-presence, understanding, and confidence. Participants commented on the aspect that they could move through the people in the voxel videos which is another area to be investigated and improved. This is not only an area of improvement for the participants, but is potentially also a cultural issue. The ability to pass through a representation of a person was indicated by knowledgeable participants to raise questions around the tapu (sacredness), wairua (spirit), and mauri (life force) of the person represented in the video and is definitely an area of the VR Pōwhiri system requiring further consideration.

Lastly, knowledgeable Māori were satisfied overall with how the tikanga for the Te Rau Aroha marae was portrayed. They did stress, however, that the system should also inform potential users of tikanga aspects that they may experience at a different marae. Their opinions on the virtualisation of tikanga were favourable, but with caveats. These were that virtual tikanga should not replace physical tikanga, that the virtual tikanga is only a way to learn and share the tikanga, and that they all prefer physical tikanga.

5 DISCUSSION

As part of our research, a novel way for a user to experience a pōwhiri was created, with the aim of increasing users' understanding and confidence surrounding Te Rau Aroha marae tikanga pōwhiri. We undertook two empirical studies and implemented a VR Pōwhiri system.

Using VR to investigate understanding and confidence gains surrounding cultural aspects is an underdeveloped area of research, but current research shows that VR can be an effective form of increasing intercultural competency [6, 29, 30, 34, 35], and our research further supports and extends these findings. From our research we learned that creating a sense of presence for the users, a sense of 'being there' at Te Rau Aroha marae, was a significant reason for understanding and confidence gains and those findings

are consistent with current research [6, 30]. One participant noted that they felt that they were "part of the actual process" of a pōwhiri and that "having the karanga and the whaikōrero and actually listening ... made me feel like I was present". Additionally, one participant mentioned that they felt as if the tikanga dictating their actions in physical pōwhiri was "actually there [in the system]" and that they had to obey it, highlighting the sense of presence and building upon the findings found in current literature.

While we found that understanding and confidence increased after using the VR Pōwhiri system, we must also acknowledge that some studies reported no significant advantage of using VR for intercultural learning [13]. This may be due to many factors such as the VR hardware and the nature of the VR environment created. With our own study, we did have five participants that felt simulator sickness that could impact learning when using VR for cultural learning.

However, from our research and current literature, we can see that VR does indeed have a positive impact on cultural learning. From our research, we determined that participants engaged with the VR Pōwhiri system, and saw both their understanding and confidence surrounding tikanga pōwhiri increase. Additionally, we can infer from this increase in understanding and confidence that participants awareness and appreciation of Māori culture has been expanded. This is especially true of participants that are not from New Zealand, with one even noting that "before this [use of the VR Pōwhiri system], I had no idea it [pōwhiri] existed". This angle of exploring if participants' appreciation of pōwhiri in particular, and Māori culture in general, increased would be an interesting area to investigate in future studies.

For the first author, it was particularly rewarding to work on this uniquely tikanga Māori research with their Māori background. The researcher is of Tūhoe descent, an iwi from the Te Urewera region of the North Island of Aotearoa New Zealand. The tikanga of Tūhoe differs from Ngāi Tahu (the iwi of Te Rau Aroha marae) and it was a privilege to be able to work in the tapu environment of the marae to create a research outcome that directly benefits Te Rau Aroha marae. Working on this research has deepened their appreciation for their culture and introduced an area of HCI research that enhances and protects their culture and its traditions, while also making it accessible to a new audience. As a Māori researcher, they have also improved their knowledge of conducting research within their culture. They have gained a new appreciation for the key Māori values of whanaungatanga (relationships), manaakitanga (caring for each other and relationships), and kaitiakitanga (guardianship and protection of the land) and how these values drive research within a Māori context.

6 LIMITATIONS

Creating 3D reconstructions of the entire Te Rau Aroha marae complex, and all of the buildings and spaces within, was beyond the scope of the research. As only one visit to the marae was scheduled during the timeframe for research purposes, this provided us with limited opportunity to take photos and scans of the complex for reconstruction. Due to the limited opportunity, the fine details of the marae complex are missing.

The use of voxel videos in the system also had limitations. Only a small amount of videos can be played concurrently, with the system slowing significantly as the number of videos increases. The recording space for the voxel videos was also limited. At Te Rau Aroha, chairs are set up in the wharehau interior for the people present to sit at. These are set up as two groups of chairs facing each other and take up a significant amount of space. Unfortunately, the recording space available to record was not large enough and voxel videos needed to be recorded with a reduced pōwhiri setup of two chairs on either side facing in towards each other.

Another limitation was the availability of actors and accessing resources to complete the development of the system. Ideally, we would have had actors from Te Rau Aroha marae to perform the pōwhiri steps but this was not possible. Instead, we decided to record local Māori and research peers with audio supplied by people who would perform the steps at a physical pōwhiri. The limitation in this approach was that only a specific group of people have the skills to perform these steps and not all of them are willing to provide the audio recordings for a virtual pōwhiri.

We also need to acknowledge some of the limitations that stop us from making an assertive determination in answering the research questions, e.g. limited participant numbers and the use of some non-standardised questionnaires. However, we believe that our findings are reflecting true improvements and that they can be used as a base for further research.

7 CONCLUSION AND FUTURE WORK

We created a new and novel way to experience a pōwhiri at Te Rau Aroha marae to investigate the potential of using VR to increase understanding and confidence of tikanga pōwhiri. To do so, we implemented a VR Pōwhiri system and conducted two studies.

As a first step, a preliminary VR Pōwhiri system was implemented and taken to Te Rau Aroha marae to run a *Cultural Evaluation Study* with mana whenua to determine if our VR Pōwhiri system was culturally accurate and correctly depicted the tikanga pōwhiri of Te Rau Aroha marae. All participants from the *Cultural Evaluation Study* enjoyed the system and could see the potential of VR as a cultural learning tool. Further insights gained from this study helped us to understand how the tikanga pōwhiri could be improved and which parts were missing, informing the adaptation of the system for the *User Study*.

The *User Study* was the culmination of the research and worked towards answering our research questions of determining if pōwhiri understanding increases following the use of the VR Pōwhiri system, along with if confidence surrounding pōwhiri increases. The pre- and post-study quiz results showed clearly that the VR Pōwhiri indeed increased users' understanding and confidence and all quiz questions were answered much more accurately after the use of the system. Similarly, six of the seven confidence statements exploring users' confidence in attending a real pōwhiri in the future showed a significant increase post-exposure, with one exception regarding feeling 'nervous' to attend a pōwhiri. It would be interesting to investigate the reason that the VR Pōwhiri could increase confidence but did not elevate the degree of anxiousness at a similar rate.

With this research we provide a base for future work into the virtualisation of tikanga and many more questions and avenues are

open for exploration. From a technical perspective and specific to our system, is the need to revise the navigation metaphor and to refine the voxel videos alongside with the integration of a larger manuhiri group. From a cultural perspective, the portrayal of the tikanga steps, especially the interior steps, need to be improved to better align with the tikanga at Te Rau Aroha marae, including updates of the narration and what is emphasised in those.

In a more general sense, further investigations into the virtualisation of tikanga would be valuable to inform future developments. Feedback from knowledgeable Māori such as kaumātua (elders) and tohunga (experts) would allow us to better navigate virtualising tikanga and all of the cultural and spiritual considerations that need to be considered. Questions such as does a virtual pōwhiri hold the same tapu as a physical pōwhiri and if the mana of speakers present at a physical pōwhiri is also present in the VR Pōwhiri should be explored in the future.

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Recently, our hoa and kaiārahi, Bubba Thompson passed away. His contributions to Te Rūnaka o Awarua and the Ātea project were invaluable and will not be forgotten. Kua hinga te tōtara i Te Waonui-a-Tāne.

8 GLOSSARY

- **Pōwhiri:** Pōwhiri is a traditional Māori welcoming ceremony. It is done to welcome visitors to the marae and determine the intentions of the visit.
- **Tikanga:** Tikanga are protocols or procedures that define how to interact within a given space. For Māori, not adhering to tikanga can have both spiritual and physical consequences.
- **Marae:** The marae is the meeting grounds where the iwi (tribe) will hold ceremonies such as funerals or celebrations. Marae consist of many different buildings such as the wharenui (meeting hall) and wharekai (dining hall).
- **Mana Whenua:** Mana Whenua are the people of the marae. These are the people that belong to the iwi of the marae and are the people of the land where the marae is located in.
- **Manuhiri:** Manuhiri are the group visiting the marae during a pōwhiri and are the ones that are welcomed on to the marae during the process.
- **Tapu:** Tapu means sacred. Everything has some level of tapu associated with it and to remove tapu, tikanga needs to be followed.
- **Kaumātua and Kuia:** These are elders in Māori culture. They hold the knowledge of their marae and it is their role to pass this knowledge on. Kaumātua are male elders and Kuia are female elders.

- **Wharenui:** This is the main building in a marae complex. In this building, important tribal business such as hui (meetings) and wānanga (teaching) takes place.
- **Karanga and Kaikaranga:** Karanga is the first step of a pōwhiri and is the welcoming call. Both sides of the pōwhiri will perform a karanga. Kaikaranga is the name given to the woman performing the karanga.
- **Whaikōrero and Kaikōrero:** Whaikōrero happen after karanga and are the speeches performed by both groups at the pōwhiri and each group will acknowledge the opposite group. Kaikōrero is the name given to the speaker of the whaikōrero
- **Waiata:** Waiata are songs and these happen either between whaikōrero or after all are done depending on the tikanga of the marae.
- **Koha:** The koha happens after the waiata and is the gifting of a gift from the manuhiri to the mana whenua. This is usually money but pre-european this could have been anything such as food or prisoners.
- **Hongi and Harirū:** Hongi and Harirū happen after the koha and is the touching of noses and sharing of breath (Hongi), along with the handshake (Harirū). This symbolises how the Atua (God) Tāne breathed life into Hineahuone, the first woman, where we descend from.
- **Kai:** Kai is the last stage in a pōwhiri and is the sharing of food. This happens in the wharekai and releases all pōwhiri participants from the sacredness of the ceremony.

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