



Master Thesis

Exploring Indigenous Knowledge through Virtual Reality: A Co-Design Approach with the Penan Community of Long Lamai

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Abstract

This study aims to explore the design process of a virtual reality (VR) application to preserve indigenous knowledge. Leveraging the community's preference for visual means of communication, a VR application was designed. The process involved working with the local Penan community in the forests of Borneo to co-design a VR application for a traditional hunting game called Nelikit and the mythological origin story associated with the game. Our methodology ensures that the application accurately represents the traditional game by community-led ownership of the design process and the final result. The findings of this study confirms that the use of VR can be an effective tool for cultural preservation and education, and that collaboration with the local indigenous community and designers is essential in the design process. Based on these findings a preliminary product (VR game) was developed. This has received much appreciation from the community and can be seen as a starting point for further research.

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¹Inga' means game in the Penan Language.

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1

Introduction

It is important for game developers not to ignore the historical fact that Indigenous people have often been denied the power, status and authority to tell their own stories. Game players will get the most powerful and authentic experiences of Indigenous insights when indigenous people are involved in the games' design and development. It is a vital act of self-determination for us to be the ones determining how our people are portrayed and our stories are told. - Elizabeth LaPensée, Assistant Professor of Media and Information and Writing at the Michigan state University (1).

Indigenous knowledge is highly valued by various indigenous communities around the world and is often passed down through generations. These communities struggle to preserve their traditional knowledge in the face of increasing industrialisation and globalisation. Therefore we found there is an increase in interest in researching how technology may be used to conserve and reinvigorate indigenous knowledge. One such technology is VR, which has the potential to offer a distinctive and immersive experience for conserving traditional knowledge. There has been various research on the importance of visual arts and multi modality education with indigenous communities, such as with the Aboriginal communities in Australia(2). Here cross-cultural, participatory community research was conducted with indigenous elementary students to analyze the significance of indigenous visual arts in relation to trans generational indigenous Lore. Another demonstration of the effectiveness of using visual methods within an indigenous framework to facilitate social change and preserve indigenous knowledge, is exemplified in the Komuniti Tok Piksa project in Papua New Guinea, which involves local communities in narrating their experiences of HIV and AIDS through designing and recording their own messages(3). Indigenous communities now have the opportunity to present their culture, history, and way of life through the creation of interactive and realistic virtual worlds.

Our study examines how VR technology could be used in collaboration with the Penan village of Long Lamai in Sarawak, Malaysia, to preserve and reinvigorate indigenous knowledge. The Penan people are traditionally a hunter-gatherer group with strong ties to Borneo's forests and waterways. Their traditional wisdom has been passed down through the years and they have a rich culture. Visual means of communication are of importance to the Penan community due to their close relation to the nature surrounding them(4). Working together with researchers, the Penan community can design and create VR material that is representative of its culture and expertise. This strategy ensures that the community has active ownership over the process and that the final VR content will be relevant for the Penan community.

1.1 Research Question and structure

In this thesis we will try to answer the question: "How can VR be used within the Penan community of Long Lamai to conserve and promote indigenous knowledge?" Our research question is based upon the assumption that the Penan have a preference for visual means of communication. Of course, recording this indigenous knowledge could be done using more traditional methods, such as making a video. However, this is not very immersive. Using VR, the knowledge not only gets conserved, but we can make an effort to enthuse the young members of the community and thus promote it for generations to come. Furthermore, this project is just a start. When successful, future researchers or the community can decide to build upon this project.

The broad overview of this thesis is as follows: The following section will explain how this unconventional topic came into being. We try to explain how an AI student ended up in the interior of Borneo to digitise an indigenous hunting game. Hopefully, this can be of use to future students eager to conduct a project in the field of ICT4D in a foreign country such as Malaysia. It gives a walk through of the process, the challenges faced, and the lessons learnt. The following chapter 2 provides a background on the Penan people and the village of Long Lamai where this research was conducted. This chapter is important because there are special circumstances with regard to the communities you work with which differentiates a regular IT project from an ICT4D project. After having a clear understanding of the people and community with whom we work, we continue with a detailed literature study 3. As there are many topics intersecting with this study, we could find an endless list of related studies. We will therefore limit ourselves to discuss the ICT(4D) studies which have taken place in Long Lamai and nearby areas, related studies on VR and indigenous knowledge, related studies on participatory co-design and ICT4D. After these introductory chapters our understanding should be adequate to explain our research approach 4, introduce our participants and go over some of the community protocols we followed during our field research. We then move on to the core of this research, the field visit 5. After this, we briefly discuss the resulting VR app 6 and the received feedback. We finish the thesis with a discussion 7 and conclusion 8.

1.2 Timeline of this project

In October 2022 we traveled to Kuching in Sarawak, Malaysia with a group of staff from the VU, Anna Bon, Hans Akkermans and André Baard and a student (the author). The goal for the staff was to visit Universiti Malaysia Sarawak (UNIMAS) with which the VU has a running partnership for information and technology for development (ICT4D) research. For a number of years the VU gives two courses on ICT4D. The goal of this discipline is to "Connect the unconnected" and bring the benefits of IT's to people in resource constrained environments (5). One of these courses "ICT4D in the field"¹ is given in collaboration with UNIMAS and the university for development studies, Ghana, Tamale. In the past years a number of students have conducted a project for their master thesis on location in collaboration with these partners (6) (7). The goal of the author was to find a topic in these first weeks, conduct research, collect the data, and then write the thesis back in the Netherlands. There were two possible routes to obtain a topic. Field visits at local communities and interviews with stakeholders. Or finding a local researcher to collaborate on a topic of their expertise. Initially the author thought it would be possible to find a topic before travelling to Malaysia; however, he was told this would be difficult since he could not be sure who had time to supervise him. We will come back to this point when we discuss the challenges faced during the project. Here follow a selection of field visits and interviews we conducted in this initial period:

October: Interview Dr. Kamil Salem

We interviewed renowned musician Dr. Kamil Salem to discuss the role of ICT4D in promoting local music and culture. He expressed concern over the disappearance of the gambus instrument and his desire to reintroduce it to the younger generation. Dr. Kamil mentioned the "rumaorama" game for introducing traditional music to children, acknowledging the influence of online streaming and television on their music consumption. The

¹https://ict4dinthefield.com/courses/course-v1:VU+XM_0008+2021_p6/about

conversation touched on the evolution of traditional Malay music, its past popularity, and the relatively small music scene in Sarawak due to a lack of parental support. Additionally, Dr. Kamil's involvement in teaching film and photography using mobile phones in rural areas was highlighted as a means of promoting tourism. The potential of AI-generated music in traditional Malay music was also discussed, with Dr. Kamil expressing interest in further exploration and potential collaborations.



Figure 1.1: The research team interviewing Dr. Karim

October: Field Visit Kampung Quap

During a field visit to Kampung Quap, the research team explored a government-established telecentre that has been repurposed as an "incubator hub" for local entrepreneurs. The visit coincided with UNIMAS students participating in a community service learning program. The team interviewed the telecentre manager, who explained that the training primarily focuses on e-commerce platforms but lacks non-technical training in areas like marketing and accounting. This highlights a flaw in the top-down approach taken by the government without sufficient research on local needs. The team also discovered that the telecentre manager personally provides training on content creation, although it is not formally incorporated into the program. Interviews with women involved in small businesses revealed logistical challenges rather than technical ones, such as transportation and finding customers. These challenges faced by local entrepreneurs and the top-down approach are common topics in ICT4D research.



Figure 1.2: The visit to Kampung Quap.

October: Finding a topic

After the initial period of various field visits and interviews, the author was notified that a researcher who previously worked at UNIMAS conducts some interesting research with the Penan community. The following contents were discussed during a zoom meeting: During the interview with Dr. Tariq, associate professor at the University of Technology Sarawak (UTS), it was revealed that he had previously worked on "bridging the digital divide projects" with UNIMAS, funded by the government. However, these projects were found to be ineffective during the COVID-19 pandemic. Consequently, Dr. Tariq shifted his perspective and began to focus on changing policies to better serve the communities. When asked about the main reasons for the projects' lack of success, he referred to a forum held in June 2022 (IDECS) and a participatory design conference that took place the previous summer. Dr. Tariq highlighted several reasons why ICT4D projects fail. One key issue is the approach taken, which is often based on identifying needs and attempting to solve them without involving the community in policy-making, engagement, and the maintenance of the projects. A detailed explanation of these challenges can be found on a website called e4sv.org(8), which outlines various crucial points necessary for the success of ICT4D projects. The conversation then shifted to the author's interests and project ideas, particularly regarding the Ooro project and the use of virtual reality (VR) as an educational tool. Dr. Tariq emphasized the importance of starting communication with the community before considering the use of technology. He mentioned ongoing projects, such as a master student's work on creating a tangible system to explore the rules of the Ooro language using physical objects, as well as a book on the Ooro language that incorporates images and uses augmented reality (AR) to explain symbols. This initial ideation session was the start of the project in it's current form.

November: eBorneo knowledge fair 2022

In early November the author and André travelled to the eBorneo Knowledge Fair (eBKF), held in Bario. The conference, focused on climate change, sustainable biodiversity, and the rich traditions of the Borneo region. Bario, known as the "land of a hundred handshakes," welcomed us with its warm and friendly community. Getting to Bario was an adventure in itself, as it was a two-day 4WD journey through the scenic logging road from Miri. There was a mix of presented studies and panel sessions. Some seemed very relevant to the region or Borneo as a whole. However, there were a number of studies which seemed completely unrelated. We were surprised there were no ICT4D related studies which were presented at the fair. Also, in our opinion, the fair lacked community participation, with only two sessions well attended by and with a high degree of local participation. The first was a "onthe-ground" session on self-guided hiking trails intended to promote tourism in the area. Unfortunately, we missed this, as we were still driving to Bario. In our opinion, a session like this is a great example were both community members and researchers can make use of a conference being "on location". Another session, which was of great importance to the local population, was the presentation and discussion on land rights. As seen in subjection 2.1.1, land rights are an important issue for most of the Orang Ulu (the name for the Dayaks in this area) and were therefore well attended by the Kelabits of Bario and it's surrounding villages. After the conference ended, André and the author decided to stay a few days longer, to learn more about Bario and the area. We were fortunate enough to get in touch with knowledgeable Bario local, David Liang. David studied linguistics in the UK and was well known with the various projects which were undertaken in Bario, such as the micro-hydro project and the solar farm to which he showed us around. We also visited the local radio station (which he solely ran) and the salt mine. Finaly, he was working on a project where he was marking objects and locations of importance with NFC tags. This information contributed greatly to our understanding of the area and could be interesting as projects for future students wanting to conduct an ICT4D related study in the area.

1.2 Timeline of this project



Figure 1.3: The eBorneo knowledge fair.

December, January: Ideation and preperation

During this time we had to come up with the actual plan of the project. Knowing the topic: "How to conserve and promote indigenous knowledge using VR" it was still a difficult process. The topic itself is quite niche, which made it hard to define the methodology. Eventually it was decided to combine a more traditional ICT4D approach such as the participation action research in software methodology augmentation (PRISMA)(9) with a new approach developed by us. More on the methodology in chapter 4. Furthermore, the author joined the Advanced Centre for Sustainable Socio-Economic and Technological Development (ASSET)¹ as a visiting Fellow. The rest of this period was spend developing a prototype which would be brought to the community as an "intervention", practical organisation for the upcoming field trip and a holiday break around Christmas and the new year.

January: Field Visit

In January we traveled to Long Lamai to conduct our field research. To travel to Long Lamai you can either drive or fly to Long Banga using a small "Twin Otter" plane and from there you have travel upstream using a longboat for 1.5 hours to Long Lamai itself as seen in figure 1.4.

Long Lamai has had many outside visitors over the past decades, however, traditional customs still have to be followed. As a newcomer you have be "introduced" to the community. This is usually done by meeting one of the elders in a public place and greeting the other villagers. On the Saturday of our arrival, Garen Jengan, the community-scholar of Long Lamai was not feeling well and unable to greet us. As a consequence, we stayed in the homestay until Sunday morning when we went to the church service, this way the whole village could see us. Since Dr.Tariq has worked with the community for many years, they could see the author was with him which helps with making them feel at ease having a foreigner in the village. After this affair, the author was free to walk around and explore the village. Sunday afternoon the author joined the local weekly football game, not being a very strong football player it was a good moment nonetheless to be introduced to the community. We used Sunday worning the author was accompanied by a group of the local youth for a walk in the surroundings of the village, it was right around harvesting time so there were many villagers in the padi fields. This was a good experience to see how people

¹https://asset.uts.edu.my/research-fellowship/



Figure 1.4: Traveling to Long Lamai.

lived and worked in the village. Unfortunately, there was not enough time during this visit to go to the forest and experience the exceptional Penan skills in the jungle. That evening we held our last design session in the community hall and the author was awarded with the Penan name: *Lakai Kebit*, which means something akin to tall man. It is not uncommon for Dayaks to give outsiders a name as a sign of respect and friendship. Tuesday morning we departed Long Lamai, being waved goodbye by the family running the homestay and other people from the village.

February: Development

February was spent building the VR application based on what we designed during the sessions in Long Lamai. There is not much to be said about this process, except that developing from a older computer and the first few weeks without the VR headset itself was challenging at times.

Februari: Unity Workshop UTS

The author was approached to deliver a Unity workshop at the upcoming summer school hosted by UTS. The objective of the summer school is to engage teams in the development of augmented reality (AR) and virtual reality (VR) applications for cultural institutions.



Figure 1.5: The Long Lamai longhouse.

Given that the utilisation of the Unity engine will be a key aspect of these applications and recognising that participants from diverse backgrounds may lack familiarity with this software, the author was invited to conduct the workshop with the purpose of imparting essential skills and knowledge in Unity development. Since the background and experience of the participants varied, the workshop had to cater to everyone. We had three sessions divided over two days. In the first session, we followed a tutorial from the Unity website that introduced participants to the software¹. In the end, the author asked the participants which topics they would be most interested in learning. On the basis of these answers, the second session was held; explaining these topics. During the final session the author tasked the participant to design a small game. The author then explained the steps he had to go through to create this game, showcasing the development process. Together, this was a very informative experience for the author; learning how to deal with differential teaching a topic unbeknownst to many. Figure 1.6 shows the workshop.

March: Final tests and summer school

In march the team conducted the final tests and the author joined a summer school called: digitization of indigenous knowledge for extended reality and culture (DIKE)², a week long workshop working with an interdisciplinary team on an AR application to preserve cultural

 $^{^{1}} https://learn.unity.com/tutorial/hackathon-quickstart-guide?tab=overview$

²https://asset.uts.edu.my/dike2023/





Figure 1.6: The Unity workshop at UTS.

heritage. The workshop was held at the Borneo Cultures museum, a brand new museum and the largest in South-East Asia. The author worked on the Rattan Basket Weaving project alongside a diverse group of students and experts from different countries. The ten days spent at the Borneo Cultures Museum in Kuching were filled with creative exploration, interdisciplinary collaboration, and meaningful discussions on the intersection of culture, heritage, and technology. It was inspiring to see how the summer school brought together academia, community groups, museums, and industry to create innovative applications that bridge the gap between the physical and digital worlds. The workshop had many similarities with the thesis itself and was a useful experience. The author's team won the prize for the best project, awarding one of the Malaysian team members to travel to Berlin. Furthermore the team was asked to write a paper for the upcoming International Heritage and Cultural Conservation Conference $(InHERIT)^1$ to be held in Sibu on the 16th, 17th and 18th of August. This resulted in the following paper: Manai Uwi - Symmetric AR Application Development for Embodied Knowledge in Interdisciplinary Teaching Contexts, of which the submission was accepted and will therefore be published in the scopus indexed journal Journal of Sustainability Science and Management and Planning Malaysia Journal (PMJ). See the appendix for more 8.

April: Writing conference papers

Based on this research project, the author, together with his UTS collaborator, Tariq Zaman, decided to write two papers with the intention of submitting them at INTERACT

¹https://inherit.uts.edu.my/



Figure 1.7: The summer school.

2023¹. Interact is the 19th International Conference of Technical Committee 13 (Human-Computer Interaction) of IFIP (International Federation for Information Processing). The first paper is a short paper focusing on the design process and it forms the basis of this thesis. The second paper is a demo paper and focusses on the resulting VR application. The papers were accepted and the author will present them in August 2023 in York. Both links to the articles can be found in the appendix 8.

June: VR symposium VU

In June the author presented this research project at a VR symposium at the VU, hosted by the XR-Community and the Network Institute. Researchers presented VR studies from varying fields on topics like police training, cognitive psychology, and flood preparedness. This was a great way to connect with other researchers and discuss methodologies with other's who were interested in this study. Figure 1.8 shows the event.





Figure 1.8: Presenting this research at the VU VR Symposium.

¹https://interact2023.org/

1.3 Lessons learned

Some of the lessons learned from the process of conducting a research project in this manner:

- Identify researchers beforehand, get in touch with them to get familiar with their projects. You will almost definitively have to work with someone, as you lack the local contacts to organise a project and get in contact with communities.
- If you go in completely "blind", it could be very hard choosing a project. The pressure you feel in this stage might lead you to pick a project you would rather not have done.
- Make sure you plan everything in a concise time period, it can be easy to plan things too distant in the team, making the whole project a lot longer then you initially intended to.
- Bring the right equipment. Make sure everything is in order before you leave as this will make it much easier during the project.
- Finances, the VU supported the flight from the Netherlands to Kuching and the field visit plus some additional internal travel in Sarawak was supported by UTS. However, most was financed by the author. This is something to take into consideration.

$\mathbf{2}$

Background

As this is not an ethnographic study of the Penan, we shall not dive in too deep to explain Penan society and traditions. However, since we worked with the Penan during this project and we digitised their game and story we shall give a brief overview of the history of the Penan, which explains the current situation they are in. We also touch upon a number of characterising aspects of Penan culture and the situation of Long Lamai, the village where we conducted our research. This will ensure the reader understands were the game and the story originate from.

2.1 History of the Penan and their region

[The Penan] have some amazing peculiarities. Though great hunters they have no dogs. They have no houses, using only temporary shelters made of boughs and leaves, though in certain instances they make use of caves. Notwithstanding this, they are healthy and strong.... They do not till the soil, nor do they use boats, having indeed an aversion to rivers and large streams. – Charles Hose, administrator, naturalist, anthropologist and geographer in Sarawak from 1884 to 1907.(10)

The writer and journalist Paul Malone aptly named his book on the Penan and their struggle to protect their forest, "The peaceful people" (11). This books is our primary source for the information found in this section. In the late nineteenth century, when the British adventurer James Brooke helped the sultan of Brunei quell a rebellion, he was granted the title: Raj of Sarawak. Over the years he and the subsequent "White Raja's" as they were called, expanded their territory to the north-east and land inwards to the current territory of the state of Sarawak. The area where the Penan lived was in the north-eastern part of Sarawak, with a number of Penan living across the border in the then

Dutch-East-Indies (Now Indonesian Kalimantan). Before large scale logging started in the 1970's most of the island of Borneo was covered in tropical jungle. This is where we find the Penan, who unlike their neighbors, such as the Kelabit, Kenyah, Kayan, Punan and Iban, did not practice farming techniques. They did not live in longhouses. Instead, they roamed their forests, and are the undisputed masters of their environment. Importantly, unlike their neighbors the Penan did did not adhere to headhunting rituals. The Penan are renowned Pacifists and there have been very few recorded instances where Penan have resorted to violence. During colonial times this occasionally led them being the target of headhunting raids. Brooke's colonial officers, although tolerant of their subject's religious and cultural practices, did not accept headhunting in their territory. This lead them to many expeditions in areas not fully under their control. By the end of the 19th century they had mostly succeeded. The local Dayak (the indigenous people of Borneo) communities realised that in return for marginal taxation and overlordship of the government they got peace and security in return. This peacemaking culminated in the war-canoe regatta, where instead of combat, the tribes would race each other on the water. This tradition has survived into modern days as can be seen in figure 2.1. The Penan benefited greatly from the prohibition of headhunting.



Figure 2.1: Image from the author of the annual Sarawak regatta in Kuching 2022

WWII

Naked but for a tiny sirat about his loins and clutching a blowpipe in his hand stood a Punan [actually a Penan]. I called out to him, and his shy worried expression changed to a grin of recognition. As he began to walk forward, almost 30 more Punans [Penan] materialised out of the jungle on all sides of us. Not so much as a snapped twig, a cough had disclosed their presence, and yet they had been following the party for the past two hours. – Major Bill Sochon, Guerilla Leader of Z-force during operation SEMUT in WWII(12)

During the second wold war, Sarawak (and the rest of Borneo) was not spared from Japanese invasion. The main objective of the conquest was to secure the oil fields of Miri and Serian. Initially the local Bornean population accepted Japanese rule, seeing how their colonial overlords were easily defeated by the Japanese. This removed the concept from the local Dayak population, that white people would poses some sort of magical abilities. As in other parts of Japanese occupied Asia, westerners were interned in prison camps. However, as the occupation continued over the years life became difficult. With Borneo's supply lines being cut off by allied blockades, essential supplies such as rice and cloth became scarce. This, combined with food requisitioning and the often violent treatment of the locals; made people's resentment against the Japanese rise. In 1945 a group of Australian, British and New Zealand special operatives, landed in the in the upper Baram (Major river in the area) area to establish a local guerilla force to harass and contain the Japanese. Among them was Tom Harrison, a charasmatic character who would later become curator of the Sarawak museum and documented many findings in the area. Many Dayaks were employed in service of the operation. The Penan with their unrivalled jungle skills helped as guides and porters.

2.1.1 Post-colonial Times and threats

With Malaysia declaring independence in 1963 and Sarawak joining the federation as a state, a new era started. However, for the Penan this new era came with many hardships. The development of logging and the construction of hydrodams in Sarawak have had profound effects on the Penan community(13). Large-scale logging operations began in Sarawak in the 1970s as a result of a boom in demand for tropical timber. As large areas of their ancestral lands were being logged, the Penan, who had since time immemorial lived in the forest, found that their way of life was in danger. The logging activities not only disrupted their traditional hunting and gathering practices, but also destroyed sacred sites, believed to harbour spirits and resulted in biodiversity loss in the region. Furthermore, the construction of hydrodams, such as the Murum hydroelectric project(14), has exacerbated the challenges faced by the Penan. The government embarked on ambitious dam projects to meet the increasing energy demands of the state, displacing indigenous communities in the process. The Penan, who have a deep spiritual and cultural connection to the rivers and forests, have been forced to relocate from their ancestral lands due to the flooding caused by dam reservoirs. This displacement has resulted in the loss of their traditional livelihoods, cultural heritage, and social cohesion. The Penan have vigorously campaigned to have their rights and their lands protected. To oppose the encroachment on their traditional land, they have participated in demonstrations, blockades, and legal actions (15). They have encountered many difficulties, such as intimidation, violence, and marginalization, despite their non-violent opposition. The impact of logging and dam projects on the Penan goes beyond the loss of land and resources. It has disrupted their social structures, eroded their cultural identity, and led to economic dependence on external sources. This caused the Penan to face tremendous hardships as they strive to protect their forests, maintain their way of life, and secure a sustainable future for their community. Efforts from local and international organizations, as well as the growing recognition of indigenous rights, have brought attention to the struggles of the Penan and other indigenous communities in Sarawak. The recognition of their rights to land, self-determination, and cultural preservation is crucial in ensuring the well-being and resilience of the Penan and the safeguarding of their unique cultural heritage for generations to come.

Pressure from society, the government and religious leaders made most of the Penan communities settle. The communities were settled in different times, with some retaining the majority of their traditional ways and others adjusting to modern influences and adopting new practices. The next section will briefly describe some of the most identifying traditional ways of the Penan.

2.2 Characteristics of Penan Society

A few of the characteristics of Penan society, as they were recorded in the first half of the 20th century, make them stand out from other Dayak groups. These characteristics make us better understand some of the particularities we encounter during our co-design research. This is far from exhaustive and we therefore urge the reader to explore a broader range of sources and perspectives to gain a comprehensive understanding. Most of this information comes from the aforementioned book: "The peaceful people" by Paul Malone (11).

The Penan traditionally have a high degree of gender equality, with women not being hesitant to take up work considered a man's job in western society. Strikingly, women participated with conviction during the anti-logging protests; not understanding why the men got arrested while they didn't. When the paternity of a child is disputed, a women's word is worth as much as an man's. Divorce is possible, when it's necessity can be proven. Men do most of the hunting and women most of the cooking. However there are no issues if men cook or women hunt if the need arises. One of the most striking examples of Penan equality is the importance of sharing. When a hunter returned, their prize would be divided between the whole community, making sure that the parts of the animal itself would also be equally divided. This way when food was abundant everyone would be satisfied, but when it was limited everyone would endure hunger. In modern days, with the introduction of money and larger communities, this practice of sharing is becoming more difficult. The Penan would traditionally not eat domesticated animals, only the ones which roamed wild in the forest. This characteristic has has mostly disappeared with most villages now raising poultry and sometimes other livestock as a source of food. Next to the importance of sharing, a key particularity is the importance of stewardship in Penan society. The act of preserving (molong) and managing forest resources is of utmost importance. To make sure the forest would keep providing them with the necessary products, Penan would make sure to not harvest certain plants too much, not to fell large trees or cut down trees which provide food and shelter to animals. Disputes in the communities are solved peacefully, with the community debating on the right course of action, drawing from the knowledge of old stories. A possible solution could be to transfer valuables to the aggrieved party. One example comes from an anecdote we picked up, where a visiting researcher got into a quarrel with the host family. Instead of the researcher being asked to leave, the family decided to move away from the village, after which the researcher could not maintain their presence for long. Only years later the family moved back to the village, into a new house. Finally, before the arrival of christian missionaries in the area in the 1930's, the Penan followed "the old religion" where they believed spirits could live in rivers, trees and mountains. These days, the overwhelming majority of Penan are devoted Christians.

2.3 Long Lamai

The village of Long Lamai is located in the interior of the Malaysian state of Sarawak on the island of Borneo close to the indonesian border. The village was settled in the 1950s by 16 Penan families from the Balong River area and has grown to over 114 households (4).



Figure 2.2: A map of the location of Long Lamai.

The government opened at primary school in 1960, which is attended these days by children from the surrounding area, one of the teachers is from Long Lamai itself. This is a good development as it is important that education is catered towards the needs and interests of the Penan. As of today a few of the students made it to university and one works for a government agency in Kuching. Later in the 1960's the Borneo Evangelical Mission build the first church. The village is self-sufficient in it's production of rice. Children roam the village freely and adults spend most of their time in the padi fields a short walk from the village. However, the relationship to the forest is still close, many older members of the community still spend their time hunting and gathering for forest products. As Long Lamai is strongly opposed to Logging and the building of hydroelectric dams, they seek support in places other then the government. One such places is the academic world. The community has developed close ties with universities in the area such as UNIMAS and more recently UTS. Furthermore, NGO's such as the Bruno Manser Fund¹ help with the research and development of improved rice farming techniques. This way, Long Lamai is able to provide researchers with an opportunity to conduct research. In return they benefit from some

¹https://www.brunomanser.ch/en/about-us/aims/

of these projects such as a micro-hydro generator, funded by the Japanese government and put in place by UNIMAS. There are also a number of solar panels funded by the Japanese. Long Lamai has made the conscious choice not to get road access. This way the community retains their relationship with the forest, there is more control of comings and goings in the village and the village "remoteness" might prove more attractive to tourists. Currently the village is mainly accessed by boat transportation over the river. In 2007 community elders noticed that many villages in the surrounding areas were loosing their youth, as they looked for jobs in the towns and cities. To counter this they made the decision to try and provide them with work. In 2009 a telecentre was opened with help of UNIMAS and a transportation committee was set up. Employing villagers to transport people and goods between Long Lamai and other villages, mainly Long Banga, the closest town with road access and an airport. The introduction of a telecentre and these days, prepaid broadband satellite internet services, such as connect me now make sure most of the villagers are connected to the internet. However, this and the fact that many youth who go to secondary school have to go to towns like Maraudi causes the younger generations to be become less interested in traditional Penan knowledge. A number of research projects trying to leverage modern technology to solve these issues have been conducted. We will discus these in depth in 3.1.

3

Related Work

Over the years, there have been various studies that have used modern information and communication technologies to conserve and promote indigenous knowledge, VR being one of them. In this chapter, we briefly discuss a selection of these studies to better understand the task at hand.

3.1 IT studies and Long Lamai

In Zaman, Yeo and Jengan (2016) (16) the Oroo' language of the Penan is studied. This sign language is used in the rainforest to communicate between groups. It uses twigs, branches, and leaves attached to a signage stick to create different messages. The study then uses community-based research design to develop new IT solutions to preserve the Ooro' sign language. This study shows that the Long Lamai community is open to new technologies to help the preserve their traditional knowledge and bridge the generational gap between the elders who still maintain this knowledge and the youth who might be more interested in new technologies. Some of the outcomes of this research were an adventure game, teaching the Ooro' sign language to Penan children (17), custom made Ooro' short message signs (SMS) (18) and a tangible system for creating new Ooro' rules (19). The goal of the Ooro' game was to teach children the Oroo' sign language. Findings of the study did not show a significant increase of retained knowledge of the Oroo' language. It did however provide us with feedback which is useful to the way we will design our game. Instead of text directing you through the game the participants rather had a voice based system, furthermore they preferred a more local environment in the game, we can use this feedback for our own game design. These studies show that through participatory design methods, researchers can develop innovative solutions to conserve indigenous knowledge.

3.2 VR and indigenous knowledge

VR applications have recently undergone significant developments, including hand gesture tracking, which presents new opportunities for creating immersive user experiences. Although there have been numerous studies on gesture elicitation, many lack validation and fail to include a diverse group of participants. This research addresses these limitations and explores the digitalisation of intangible cultural heritage in collaboration with San tribes in southern Africa (20). Specifically, the researchers focus on incorporating gestures as embodied interactions in a VR implementation of a traditional San hunting story. The study includes an in situ elicitation of natural gestures, co-designed integration, and implementation of a VR story with grasping and gestures. The findings reveal the anthropological value of incorporating gestures determined by an indigenous community. Many of the challenges faced in this project resemble those of our research (21).

Another interesting example of VR and indigenous peoples is the fourth VR project (22). The fourth VR is a database of VR cinema and games made by or with indigenous people. The study explores how indigenous creators utilise VR technology to tell their stories and resist colonial frameworks. Through case studies and analysis of the Fourth VR database, the authors identify a growing Indigenous-centred VR production framework that features Indigenous Futurism, native languages, activism, and interconnectivity.

3.3 Paricipatory co-design and ICT4D

To understand how we should design our methodology and conduct respectful inter-cultural research we can look to the fields of participatory co-design and ICT4D. One possibility for us would be to follow an approach such as Participatory action Research In Software Methodology Augmentation (PRISMA) (23). Here researchers developed a methodology which combines the formal and technical aspects of software development with the essential humanistic considerations. While the formal components encompass requirements analysis, design, implementation, and testing, the soft aspects revolve around understanding the community's desired changes, motivations, and the complex social and political dynamics involved. Neglecting these non-technical factors can lead to poor system design, unusable interfaces, budget overruns, and project delays. Therefore, this methodology aims to merge both the hard and soft aspects, ensuring a comprehensive approach that addresses the social dimensions alongside the technical requirements of the project. This methodology was used in the eToro project in Long Lamai (24)

4

Research Approach

Our research approach is centred on the issue of loss of indigenous knowledge, a problem that many indigenous communities around the world face. As shown in the introduction, we believe that the Penan community can benefit from multimodal media 1, such as VR, which allows users to fully experience a virtual simulation. VR has the added advantage of being fully customisable, allowing applications to be modified according to the needs of users and customers. To ensure that the Penan community has full ownership over the process and content, we presented a prototype VR application to a panel from the Long Lamai community. Our approach is divided in four stages which can be seen in figure 4.1. Every stage has an input and an result. The four stages are as follows: 1) Exploration, 2) Ideation, 3) Documentation, and 4) Co-design. Each stage lasted around 1.5 hours and the sessions were held on two different moments. As there is not much similar research we can base our approach on we had to devise our own ad hoc approach by integrating insights from other ICT4D and participatory design studies, as well as drawing on the researchers' previous experiences and the unique characteristics of the project. The project most similar to ours is the VR project in Namibia (discussed in 3.2) and therefore our approach is inspired on the similar successful approach used in (21).



Figure 4.1: Our four stage research approach.

4.1 Participants

Our group of participating co-designers consisted out of seven people: Two elders, two young men, two young women, and one teenage boy. One of the younger men was the village school teacher. The younger participants would help us translate between English and Penan language when there was any form of confusion. They had no previous experience with VR.

4.2 Community protocol

Researchers developed a community protocol with the Long Lamai community using sketches (4) (25). By designing this protocol using visual probes, cross cultural dialogue can be promoted. The protocols were developed together with multiple focus groups and approved by a community council of elders. It was then tested on various occasions with visiting researchers. The sketches can be seen in figures 4.2 and 4.3



Figure 4.2: Sketches on consent, research initiation, equility and trade-off.

Consent is essential; as a researcher, you need consent from the community to collect data. **Research initiation** demonstrates that the community must be fully informed and give approval before the research can commence. **Equality** emphasizes that community members should have an equal voice in the project and maintain ownership of it.



Figure 4.3: Sketches on misapprehension, mutual exchange, knowledge rights and goals.

Trade-off highlights the importance of compensating community members for their time spent assisting researchers. **Misapprehension** stresses the need for ongoing dialogue to avoid spreading incorrect information about the community's culture and customs to the wider world. **Mutual exchange** underscores the necessity of a balanced information exchange, where researchers explain their project and findings while the community shares their indigenous knowledge. **Knowledge rights** emphasize that the community retains ownership of their information, and dissemination requires consent from the community. **Goals** signify the collaborative efforts of researchers and the community to achieve their respective objectives, which may not always align.

We ensured adherence to these guidelines throughout our project to ensure that all parties feel respected and maintain a sense of control, thus fostering a lasting relationship between the community and the researchers. $\mathbf{5}$

Field visit

5.1 Stage 1: Exploration

5.1.1 Input: Prototype

In our study, we developed a prototype using the Unity Engine for mobile VR, with the purpose of showcasing some of the possibilities of VR. The decision to use mobile VR was made due to its cost-effectiveness and accessibility, as many community members already have smartphones that are capable of running VR applications. To achieve a feasible performance on lower-end devices, we adopted a stylised approach to the models rather than striving for realistic visuals. A screenshot of the demo can be seen in Figure 5.1. The prototype consisted of two Penan character models set in a forest environment resembling Long Lamai's natural setting. Additionally, the prototype included various objects commonly used by the Penan in the jungle, such as a basket, a blowpipe, blowpipe darts, a lighter, a parang (machete), and a cooking pot. To enhance the immersive experience, the prototype featured a boar that roamed around and produced sounds, accompanied by sape music in the background. The prototype also included several interactions, such as picking up and dropping items by gazing at them and using floating buttons in the air. Additionally, users could light up the fire with the lighter and place the cooking pot on it. The prototype aimed to provide a recognisable environment, with the goal of eliciting feedback.



Figure 5.1: A screenshot from the prototype

5.1.2 Result

5.1.2.1 Visual.

The participants provided valuable feedback on the prototype's visual elements. Here follows a list of the suggestions:

- The environment is acceptable, but the forest could be more lush.
- The colour of the sky would normally be blue. However, the colouration between the colour and the time of day was observed.
- The boar was well received, but there could be more animals.
- The character's gender was identified; however, it was noted that the man should carry and wear more items to identify him as a man. (A parang / machette, blowpipe, etc.)
- The woman should wear different clothes then a T-shirt.
- The "typical" penan items were recognised; however, the bask was too large, and the type of basket depicted in the prototype, specifically used by Penan women.

5.1.2.2 Interaction.

All participants had the opportunity to interact with the items in the scene during the prototype testing. Upon a brief explanation, the two younger men effortlessly engaged with

the items. However, the other two participants faced some difficulty initially. However, with the help of the successful participants who explained the interactions in the Penan language, both were eventually able to effectively engage with the items. The participants demonstrated keen interest and excitement towards this new technology, particularly since the prototype represented their local environment.

5.2 Stage 2: Ideation Session

5.2.1 Input: Video

To assist in the ideation we presented a video from the VR research project in Namibia (20), which we discussed in the related studies 3.2. After getting accustomed to VR by using the prototype, this video would show what a fully developed VR application would be capable of. The hope was that this input would spark the imagination of the participants for applications specific to the Penan community.

5.2.2 Result

Following this demonstration, participants were asked if they thought a similar VR application would be of interest to the Long Lamai community. It was noted that children in the community would likely find such technology intriguing. Additionally, the researchers highlighted that VR technologies have been utilized for training purposes, such as in the field of surgery. The participants suggested that simulation activities, such as fishing or hunting, could be of interest to the community. Furthermore, the participants suggested that a simulation of the traditional Penan game, nelikit, could also be an interesting use case for VR technology. It was noted that one of the researchers had previously conducted research on this topic, and therefore we collectively chose this game as the topic for our co-design session.

5.2.2.1 Inga' Telikit.¹

nelikit is a traditional hunting game played by male Penan, in which players use a blowpipe to catch rattan rings of varying sizes that are thrown by other players 5.2. The telikit, or rattan ring, serve as a representation of wild boar or other animals, and the game can be seen as a form of exercise. By using a blowpipe, the player must successfully catch the telikit. It is usually played by teenagers, so they can practice their skills before the actual

¹Inga' means game in the Penan Language.

hunting. The players can choose between a number of "moves". There is an overhead throw, a side throw (left or right), or a low-front throw. The game itself is not usually being played by community members anymore, the younger generations now prefer to spend their leisure time differently.





Figure 5.2: Playing nelikit. The rattan ring is called telikit

5.3 Stage 3: Documentation

5.3.1 Input: collecting the story.

The origin of the game can be found in the mythological story of nelikit. The genesis of nelikit is at risk of becoming permanently lost. The story was first manually documented in 2013, during a visit of dr. Tariq. The initial script of the story was written by Garen Jengan, a community elder. However, due to his lack of recollection of the details, it was necessary to locate the source of the story. Tamin Pitah, a 97-year-old Penan elder, was identified as the original storyteller, and efforts were made to record his oral account. The narrative was captured through both video and audio recordings, which were later transcribed and translated from the Penan language into English.

5.3.2 Result

The following text is the collected and translated story of nelikit: Once upon a time, there were two giant spirits named Aka and Gugak who were searching for a place where they could live forever. Aka decided to search the skies, while Gugak searched the earth. After some time, they reunited to share what they had found. Aka had discovered a beautiful place in the skies, while Gugak had found a challenging place to live on Earth. Aka's home was a river, teeming with fish and resources. The river had a mystic nature, and if someone

caught a fish and threw its bones back into the river, they would come back to life as a new fish. Aka and Gugak were thrilled with their respective homes, and Aka began taking care of the skies and Gugak the land and its creatures. Whenever the people on earth faced a challenge, Aka and Gugak were always there to help and protect them. As the years went by, Aka and Gugak grew old. They noticed that the people on earth were afraid of thunderstorms, so they made a promise to help them even after they were gone. They told the people that if they ever needed their assistance, they could call their names in "Balei Padéng" and throw the telikit in the air. They would use rattan to tie up the thunderstorm and bring it away from the people.

5.4 Stage 4: Co-design

5.4.1 Input: The story

The last session in our process was the co-design session; here we walked through the details of the proposed VR-nelikit game, together with local designers. As input we started the session by showing a video recording of the story, narrated by Taman Pitah. This story was not known to any of the participants of the session. We proposed to sit in a circle on the ground so the participants could draw what they would like to see. These sketches can be in seen in Figure: 6.2.3.

5.4.2 Result

The most interesting results of the co-design session are as follows:

- It was proposed to tell the story through a book. This is interesting given the oral tradition of these stories. This could be seen as a metaphor for modern storytelling.
- The giants: Aka and Gugak, should be very large and see through to indicate they are not mere men.
- The game should portray the distant past.
- It should be in a small village, surrounded by nature.
- The game should be bilingual, in Penan and English.
- Girls can play too, even though in real life, only boys play the game; as women are not allowed to hold a blowpipe.¹

¹This is an interesting fact from Long Lamai and contradicts our information from the literature.

• One question that came up, was how to prevent the thrower from playing unfair and throwing the telikit far from the catcher. This did not seem a problem to the panel, who would not consider playing unfair; thus showing some of the cultural attributes of the community.



Figure 5.3: Two of the sketches the panel made, depicting their vision for the game.

6

Resulting VR app

Based on the results from the field research in Long Lamai we developed a VR game for the Meta Quest 2 using the Unity3D game engine. The reasoning to switch from mobile VR to the Quest was to make the experience more immersive and to allow for better interaction. With mobile VR the only way to interact with the application is to rotate your head and gaze at an interactive object. This is adequate for a simple application, requiring little to no interaction. However, it is not very immersive as it does not allow hand movement or small physical movements in the scene. Also, the quest is better at processing then most phones and displays a higher quality view. More considerations on device choice can be found in the discussion 7.

6.1 Feature choice

To decide on the features, we used the MoSCoW method; a method commonly used in software development to prioritise features (26). A cost / necessity trade-off is made and is then categorised in four levels of prioritisation. *Must have*, if any of these items are not included there is no minimum viable product and the result is therefore unusable. *Should have*, important but not necessary. *Could have*, desirable but not necessary. *Won't have*, not viable for an initial round of development. In our case, we managed to include the items marked in yellow, while the items marked in red will be left for future rounds of development. During these future development rounds, the features should be implemented based on their ranking in the MoSCoW system.

Must	Introduction Scene	Gameplay loop	Environment	
Should	Sound effects	Extra fauna	Tutorial	Time indicator
Could	Leaderboard system	Catching NPC	Animal interaction	
Won't	Multiplayer	Difficulty levels	Extra gamification	

 Table 6.1:
 MoSCoW Table for feature selection.

6.2 Development

The development process was quite simple and took about three and a half weeks. Since the Meta Quest 2 was not available for us the first three weeks we had to make sure the game itself was mostly done without testing it on the device. This made the last few days of development tricky, as integration was not without challenges. Furthermore, Unity offers developers a solution to automatically run the game when the Quest is connected with a USB cable. However, if the GPU on the computer is not strong enough this is not possible. If this is the case, the developer will have to build the game on the machine and then copy it to the device. After starting up the device the developer has to navigate to the game, install it and run it. This takes a lot of extra time and makes development slower. Especially since you usually continuously test the game. In our case, our laptop used to develop this VR application in Sarawak did not contain a GPU strong enough en therefore made development slower.

6.2.1 Assets and environment

Unity offers an asset store, here developers can quickly try out different game assets. These assets can be 3D models, but also specific code, plugins, etc. Some of assets are paid, but there is a wide variety of free assets too. To quickly develop the game we used the asset store as much as possible, using free assets with a creative commons licence. Most static models, such as trees, rocks and others came from the asset store. Where we could not find the specific models we needed, we used the free open source 3D modelling software blender. The choice for the Quest helped us make a more lush environment, as requested during the prototype session. We modelled and animated a hornbill (holding a special significance for many peoples in Sarawak). From the asset store we added a "generic" bird, butterflies and a squirrel. All the animals are not only animated, but they move around in the environment in different ways. This way they come to alive. The hornbill flies from treetop to treetop. Every other tree he halts for a moment. Sometimes he lets out a call; for this we used the sound of an actual Bornean hornbill, using a freely available sound file. The butterflies fly around in a limited area, sometimes halting on a flower for a moment. A waterfall was made in blender and it's water shader (determining how an object is rendered) was custom made to fit the style of the game. The characters in the game were modelled by Vanden Michael, who is a lecturer in creative media at UTS. After cleaning up the topology, the characters were rigged and animated using the online software Mixamo. The characters and the environment are developed based on the drawings made by the participants as seen in figure 6.2.3. Like the prototype, the style of the assets remained stylised, colourful and simple. Again, this makes for a playful looking engaging game. If we would have chosen a more realistic style we would have risked descending in the uncanny valley. In video games, the "uncanny valley" refers to the effect in which virtual characters or items that closely resemble actual individuals or objects elicit a sense of eeriness or uneasiness in players. It's a word used to express the unease that occurs when something appears almost but not fully similar to reality. The term "uncanny" refers to anything odd or unfamiliar, while the term "valley" refers to a decrease or fall in emotional reaction. (27)

6.2.2 Sound Design

Sound effects and music improve the quality and immersiveness of the game. 3D sounds will change in volume based on distance to the player and it will sound more to the left or right, based on the view direction of the player. The following list are all the sounds included in the game:

- Traditional Sapé music. As background music, so not a spatial sound.
- Voice over for the story.
- The sound of a rippling waterfall.
- Footsteps of the NPC. Timed to match with the feet hitting the ground.
- Sound of the hornbill's wings. Timed to match the animation.
- Sound of the hornbill's call. Timed to match the animation.
- Sound of the boar walking, snorting and grunting.
- A "victory sound" when the player catches the telikit.

6.2.3 Introduction and Story

The game begins by introducing players to the captivating story of Aka and Gugak, as explained in subsection 5.3.2. Currently, the narrative is presented through computergenerated narration using the Replica Studios software, displayed as on-screen text. Although real recordings from human narrators would be preferable, given our limited resources, the decision to utilize computer-generated narration was a practical choice. You can see the introduction scene depicted in Figure 6.1. In collaboration with our codesigners, we aimed to give Aka and Gugak a distinctly otherworldly appearance. We achieved this by making them very large (5m), changing their color from red to green and back, and finally having them fade out once the story concludes. The characters are equipped with blowpipes and wear parangs on their hips. These items were created by hand, using images from Long Lamai as references. Initially developed for the prototype, we carried these elements over to the final game. Moving forward, an effective way to further enhance the immersive experience in future versions of the game would be to transform the introduction scene into a theatrical performance, effectively bringing the story to life for players.



Figure 6.1: The introduction.



Figure 6.2: Playing the game.

6.2.4 Game loop

Once the introduction is finished the player gets teleported to the play area. Here the main game loop starts:

1. The non-playable character (NPC) will throw the telikit (the rattan ring) to the player.

- 2. The player can try to catch it with the blowpipe. If caught successfully a sound effect is played and the score will be counted.
- 3. The player should throw the telikit back to the NPC .
- 4. The NPC will run to the telikit to pick it up and continue with point 1.

An issue arises with the game loop when the player fails to throw the telikit at point 3, resulting in the discontinuation of the loop. The requirement for the player to throw the telikit is unclear. To address this, an improved version could include the NPC automatically picking up the telikit after a specific duration or when the distance between the NPC and the telikit is shorter than that between the player and the telikit. In such a scenario, the NPC should promptly pursue the telikit without hesitation. Some safeguards are put in place to ensure that the game can be played continuously and fairly. For example, if the telikit is out of reach, it will teleport back either to the player or the NPC based on who's turn it is to throw. The NPC will randomly choose a move such as: Overhead, left-sided, right-sided or lower and, it will adjust it's speed and direction with a small random amount to make the game more interesting. A screenshot of the game can be seen in figure 6.2, furthermore some of the gameplay can be seen in a video available on YouTube¹.

6.2.5 GitHub

The game files for the VR-Nelikit project can be accessed on the GitHub repository at the following link: https://github.com/BramKreuger/VR-Nelikit.

The VR-Nelikit project is licensed under the MIT License, which allows for the free use, modification, and distribution of the project's source code, subject to certain conditions. You can find the complete text of the MIT License in the project repository. Please note that while the project code is available for use, it is important to understand that due to time constraints during the development process, the code may not be extensively documented. However, efforts have been made to ensure clarity and readability within the available code. We encourage you to explore and utilise the VR-Nelikit project. Feel free to modify and adapt the code to suit your needs, and share any improvements or modifications with the open-source community.

¹Click Link to YouTube.

6.3 Test sessions

Due to time constraints and other unforeseen factors it was not possible for the author to do an extensive play test with a group of Penan participants. We did a small test with one adult and his son during the DIKE summer school week. Later dr. Tariq brought the Quest to Long Lamai for community members to play the game as seen in figure 6.3.



Figure 6.3: Garen Jengan playing VR Inga' Telikit in Long Lamai.

6.3.1 Feedback

Some of the community's feedback and personal notes on this version of the game are as follows:

- Currently, the animals such as the boar and the hornbill move around the scene and make sounds. They are however, not interactable. The community expressed their wish to be able to interact with them using the blowpipe.
- In the last version, the score is counted by a floating number during the game. The community would like to see a form of scoring. With this they could measure their performance against each other. One way could be a set amount of time or a max number of throws. The author had the idea of implementing a leader board system, where the performances could be saved on the device, so that players could try to improve their own scores and compare them with others.

- During our test sessions we noticed it was sometimes difficult to explain to the testers how the VR headset worked and how the game should be played. It would therefore be prudent to develop a tutorial.
- The NPC currently only runs to the telikit, picks it up and throws it to the player. In the future it would be an interesting addition if the NPC could also attempt to catch the telikit with his blowpipe. To more correctly mimic the actual game. This was not included in this version, because of the increased time to develop such AI behaviour.
- There are many other possible features which were not included in the game due to time constraints, which could be added in future development.
- Finally, the game is not very optimised and we noticed lag spikes while playing the game. This is mainly due to some models topography, and should be fixed in a future version.

7

Discussion

In this thesis, we tried to answer the question: "Can we use VR to conserve and promote indigenous knowledge". To do this, we leveraged the fact that the Penan community has a preference for visual means of media and communication. We established an understanding of the Penan. A variety of related studies, such as the VR project in Namibia(20) helped us to develop a methodology. We then developed a prototype and used a four-stage approach to come up with a game design of the traditional Penan game, nelikit. This design was then developed into a VR game; which was finally tested by Long Lamai community members. This study fits in with a number of studies that focused on digitising indigenous knowledge. As with similar studies, it is often hard to quantify the actual results of research. In our case, our new methodology proved successful in designing a virtual reality game. The project gave us many insights in how VR technology in this setting was received. These insights will be useful for future researchers wanting to conduct similar research.

Have we persevered indigenous knowledge? In our case, the game and story have been digitised so these will be available for future generations. However, it will only promoted if the application is being used. To this end the game should be embedded in a sustainable environment. One possible option the community proposed are the annual inter-Penan games, where people from different villages come together to compete against each other in games. They were excited by the idea of integrating our VR game in this competition. As noted in 6.3.1, the game should have some additional features for this to be possible. Another feature we initially discussed was adding multiplayer. This way Penan in different locations could compete against each other. This would give the extra benefit of Penan living outside of Penan communities a way to connect with each other through a game of their own culture. Another option would be to include some form of VR in the school in

Long Lamai, this way the technology could be used sustainably. However, for this to work future research and development is needed.

As mentioned to the author by Dr. Tariq, who has worked with the Long Lamai community for many years; there needs to be a "owner" of the technology to make sure it can be used sustainably. One or multiple actors need to have responsibility of a product and there needs to be a way that maintenance is provided to the community as, this is not possible to be done by the community itself. A local university like UTS could take up this role. Furthermore, the choice of devices can be reviewed. In this case we wanted users to fully immerse in the game, therefore the choice for the Meta Quest 2 was made. However, it was shown during our prototype that using mobile VR is a viable option with the benefits that users can use their own phones. This removes the issue of an expensive device and could be beneficial.

Finally, the author is interested in bringing the outcomes of this project and the VR game to a museum. The community protocols should be followed closely in this case, as the community should give consent to their heritage being portrayed outside of their villages. Furthermore, researchers should make sure to not misapprehend the indigenous knowledge.

7.1 Future research

Some possible future research projects could include the following:

- Can we develop a "Penan" VR toolkit for quick prototyping. And which other innovative solutions could then be developed for and with the community.
- What would the implications be for cultural identity be if Penan could connect through an online VR game which they developed themselves.
- How can VR be integrated in education, for the specific case of the Penan.

8

Conclusion

In conclusion, this thesis highlights the significance of developing innovative approaches to preserve indigenous knowledge. Through an extensive exploration of the Penan community, literature review, and the creation of a VR game using participatory co-design, valuable insights have been gained and contributions made to the field of ICT4D and co-design. The study demonstrates the feasibility of co-designing a VR application for preserving and promoting indigenous knowledge, aligning with the Penan community's preference for multimodal media and incorporating existing ICT4D and co-design practices. The research also sheds light on the introduction of new technologies, such as VR, within remote communities like Long Lamai. While this study acknowledges limitations, including the sustainability of technology in remote settings and the trade-offs of development within time constraints, these limitations offer opportunities for future research to explore and expand upon the findings.

Recognizing the unique nature of Penan society and the challenges it faces, it is crucial to preserve their cultural heritage for future generations. This study aims to serve as a stepping stone for future research and initiatives dedicated to preserving the rich cultural heritage of the Penan. By actively involving the Penan community in the design and evaluation processes of the VR application, a sense of empowerment and ownership has been fostered, enabling them to continue safeguarding their indigenous knowledge and traditions. It is our sincere hope that this study inspires ongoing efforts to celebrate and protect the Penan culture, ensuring its vitality and relevance for generations to come.

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Appendix

Publications

Here follow the three articles authored or co-authored by the author of this thesis. They were written during or after this research project. As they are not available on the respective journal's websites (as of the date of this thesis' submission) they can be found on google drive. Please note that the link to this drive may not work indefinitely.

- The paper on our project from the Dike summer school: Manai Uwi Symmetric AR Application Development for Embodied Knowledge in Interdisciplinary Teaching Contexts by Cubasch et. al. To be published in the Journal of Sustainability Science and Management and Planning Malaysia Journal (PMJ). Link to Google Drive
- The short paper for the Interact conference 2023. Exploring Indigenous Knowledge through Virtual Reality: A Co-Design Approach with the Penan Community of Long Lamai by Bram Kreuger and Tariq Zaman. To be published in the Lecture Notes in Computer Science (LNCS) series in the INTERACT 2023: Proceedings of the 19th IFIP TC 13 International Conference. Link to Google Drive
- The demo paper for the Interact conference 2023. Ingá Telikit: A Virtual Reality Game for Learning Penan's Hunting Techniques by Zaman et. al. To be published in the Lecture Notes in Computer Science (LNCS) series in the INTERACT 2023: Proceedings of the 19th IFIP TC 13 International Conference. Link to Google Drive