Software Development:

Involving Tangata Whenua and incorporating Tikanga Māori

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Puritia mai te tāuru o te rangi,

Kia tina, kia whena, kia toka te manawa ora,

Tina toka te manawa ora ki hea,

Ki a Ranginui e tū nei,

Ki a Papa-tū-ā-nuku e takoto nei e …

Kia rarau iho ra nga tapuae o Tane,

Tāne te wānanga

Tāne te waiora

Tāne te whakaputa ki te whaiao

Ki te ao mārama

E Rongo whakairi ake ki runga

Kia tina, tina!

Haumi ē! Hui ē! Tāiki ē![1]

Moe mai i runga i te rangimārie, e Pa
Ka whakatapua ahau i tenei mahi ki a koe

[1] Karakia o te Whare Pūkenga ā Ngā Pou Herenga o Ngaparinga

Abstract

Over the past fifty years, software development (SD) has been dominated by Western approaches, which is widely accepted as the standard way of doing things (Diaz Andrade et al., 2021). Consequently, many software applications for specific Indigenous cultures, especially health interventions and educational software (Dobson, Whittaker, Bartley, Connor, Chen, Ross & McCool, 2017; Fleer, 1989), were developed using traditional software engineering (SE) methodologies. Although these methodologies provide the workflows and methods for developing software, they do not provide guidelines for developing Indigenous software.

While there have been numerous studies on diversity, such as gender and ethnicity in the field of Information Systems, there is very little research on the practices of involving Indigenous people and incorporating their traditional customs in the software development process.

This thesis examines the participation of Indigenous people in software development. The research specifically focuses on Tangata Whenua (Māori people, the Indigenous population of Aotearoa New Zealand) and Tikanga Māori (Māori cultural methods). Our findings are useful to those attempting to enhance Indigenous representation in software development, especially those wanting to involve Māori people and their cultural methods in the development process and design of software.

Acknowledgments

Whāia te iti kahurangi, ki te tuohu koe me he maunga teitei.

Seek the treasure you value most dearly, if you bow your head,

let it be to a lofty mountain.

This whakatauki (proverb) reminds me of the importance of determination and the pursuit of success, no matter the obstacles. My MPhil journey was fraught with challenges but overcoming them taught me valuable lessons. Despite falling short of my original goal, I am grateful for how far I have come. If you know, you know.

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E te whanau, kua tae mai te mutunga i tenei ako, he mihi nunui ki a koutou katoa!

In memory of my father, I dedicate this mahi to him. He left this world knowing, his constant support of my academic endeavours, is the reason I do what I do.

Love you dad - always thinking of you.

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1 Introduction

Many software applications are being developed for Indigenous communities, particularly to address health issues (Hensel, Ellard, Koltek, Wilson & Sareen, 2019) and to revitalise cultural heritage (Borrero, 2016; Mwangonde, Ntinda & Hasheela-Mufeti, 2021). However, the software development process focuses on Western methods, which do not adequately meet the needs of Indigenous peoples. These approaches often need more emphasis on relationships, mutual respect, and reciprocity (Starblanket, Lefebvre, Legare, Billan, Akan, Goodpipe & Bourassa, 2019; Mbah & Bailey, 2022). While the software engineering community recognised the need to change approaches when involving users in design (Davies, Bukulatjpi, Sharma, Caldwell, Johnston & Davis, 2015; Siew & Yeo, 2012), it is only recent that Māori users and their cultural methods in software development have been acknowledged and documented (Te Morenga, Pekepo, Corrigan, Matoe, Mules, Goodwin & Ni Mhurchu, 2018; Rolleston, Bowen, Hinze, Korohina & Matamua, 2021).

Despite the growing recognition, there is yet to be a general approach to Indigenous software development. As demonstrated in Chapter 2, a lack of published research discussing Indigenous design processes for digital applications leaves a significant gap in our understanding. Therefore, this thesis, based on the premise of decolonising methodologies (Smith, 2012), addresses the methods involved in developing software by, for, and with Indigenous people, highlighting the need for further exploration.

As a researcher from Aotearoa New Zealand, I centre the research exploration on Tangata Whenua (Māori people), their participation in software development and, if at all, the use of Māori cultural methods during the software development process.

1.1 Motivation

Durie (2004) explores the interface between two systems: Science and Indigenous knowledge. He highlights that scientists and Indigenous peoples navigate the inconsistencies between these different bodies of knowledge. Durie suggests that scientists “subscribe to religious beliefs” that they may not be able to articulate clearly, while Indigenous peoples incorporate scientific principles and methods alongside their values. This interaction between science and Indigenous knowledge is a “source of

inventiveness” for Indigenous researchers, who leverage insights and strategies from both domains to enhance their work. When these two systems integrate, the balance of power shifts. In Durie’s case studies, Māori researchers acknowledged the potential for “two world views” to align with “two bodies of knowledge” (2004, p. 1143). However, in one of the case studies, an Indigenous group found that simply adding a Māori component to standard scientific practice, without further modifications to the method, hindered cross-population studies. In developed countries, Indigenous people play a crucial role at the intersection of science and Indigenous knowledge. They integrate methods and elements from both systems and lead the way in creating new knowledge and innovations (Durie, 2004).

Since 1960, extensive research has demonstrated that user involvement is essential for the success of Information Systems. Scholars have acknowledged the critical need to understand the views and requirements of diverse user groups (Mao & Markus, 2004; Swanson, 1974). Engaging users in software development is vital to creating information systems that are not only user-friendly but also efficient and successful (Mao & Markus, 2004; Swanson, 1974). Kaupapa Māori Research (KMR) has gained significant recognition and publication by scholars in the health, social, and educational sectors in Aotearoa New Zealand (Bishop, 1999; Smith, 2015; Durie, Hoskins & Jones, 2017). With the emphasis on co-design that highlights the core motivations driving this research, KMR is an emerging approach that significantly impacts the co-design of software involving Māori people, particularly in Aotearoa New Zealand (Te Morenga et al., 2018; Verbiest, Corrigan, Dalhousie, Firestone, Funaki, Goodwin, & Mhurchu, 2019; Rolleston et al., 2021). KMR is further discussed in Section 2.1. Furthermore, while the contributions of open-source software development are undisputed (Wu & Lin, 2001), this thesis focuses not on individual coding practices but rather on the work of formal software teams. In Section 5.3, I consider future research regarding Indigenous frameworks for the open-source community.

As I will outline in Chapter 3, it is imperative that traditional software development processes recognise the role of Indigenous users. Unfortunately, there is a noticeable gap in the literature regarding the integration of Indigenous cultural methodologies into these processes. This research endeavours to fill this gap by focusing on how the software development process can genuinely involve Indigenous individuals,

especially Māori. This approach not only enriches the development process but also ensures that the resultant systems are truly reflective of the needs and values of Indigenous communities.

1.2 Definition of terms

The terms “system” and “software” are often used interchangeably. In this research, I primarily use the term ***software***. Software refers to software engineering results, including mobile applications, websites, and computer games.

Design and development are also used interchangeably but refer to different stages of the product creation process. Design involves planning and conceptualising a product, while development refers to the creation of the product and covers its entire lifecycle, from inception to delivery. To clarify, I will use the term ***software development*** to describe the design and creation of software.

The ***software development process***, sometimes known as the software process, involves a series of activities aimed at developing, managing, and maintaining software systems (Bourque & Fairley, 2014). A *software model* is an abstract representation of this process, and there are various models or life cycles.

In this thesis, I categorise software development processes as existing or integrated. I consider an ***existing*** process to be an established and widely used software approach, such as the SDLC or Software Development Life Cycle (Matkovic & Tumbas, 2010) and PD or Participatory Design (Sundblad, 2010). I consider an ***integrated*** process to be a combination of existing processes and/or an extension of an existing process, such as the Participatory design process is integrated with Kaupapa Māori (Māori principles and values) and Te ao Māori (the Māori worldview), extending the traditional process for Software design by Rolleston et al. (2021).

The software development team is responsible for the design and coding of the software. ***User/s*** and end-user/s refers to people who intend to use a product (Saiedian & Dale, 2000; Robertson & Simonsen, 2012). The *customer* may also represent a user but may typically advise the software development team on their contracted product. A user provides valuable feedback to the development process and product.

In this writing, I will frequently refer to ***Indigenous*** people: a person or a community who inhabited a land before the arrival of Western people, such as Māori (Indigenous people of Aotearoa New Zealand), Pasifika (Indigenous peoples of the Pacific Islands) or Aboriginal and Torres Strait Islanders (Indigenous people of Australia). Therefore, an ***Indigenous user*** is someone from a native population who may bring their unique culture and perspective to software development.

Aotearoa, translated as "the land of the long white cloud", is known as New Zealand. In Aotearoa New Zealand, ***Māori*** people are acknowledged as Indigenous by other Indigenous groups (Smith, 2012). The term ***Tangata Whenua*** means the people of the land to which Māori refer to themselves and other Māori. Additionally, I provide a glossary of Māori terms to aid in comprehending this thesis (Appendix A).

User *participation* and *involvement* are used interchangeably throughout the literature. But they have different meanings. In this thesis, user participation refers to the active collaboration between the user and the designer to create something. In contrast, user involvement is about how important and relevant the software is to the user. For simplicity and the reason that active collaboration encompasses the participation and involvement of users, I will use the term ***user participation*** to refer to both concepts. User participation in software engineering refers to the involvement of users in the software development process (Hartwick & Barki, 1994; Abelein & Paech, 2015).

1.3 Research questions

Recently, the software engineering community has started to recognise the significance of involving Indigenous users. This research explores Indigenous peoples' participation, particularly Tangata Whenua (Māori people), in software projects and the integration of cultural methods and practices in development processes.

These questions guide the research:

RQ1: *How are Māori cultural methods relevant for software development?*
RQ2: *How are Māori people acknowledged in software development processes?*
RQ3: *How are Māori Software Development Teams using cultural methods?*

1.4 Structure of the thesis

This thesis is structured as follows:

Chapter 1 introduces the topic and motivation for this research. The thesis terminology and research questions are defined, and the structure of this thesis is outlined.

Chapter 2 presents the background of the related work on Māori and Indigenous approaches to software development and a chapter summary. Here, I will answer the first research question, RQ1.

Chapter 3 presents a review of traditional and contemporary software development processes that acknowledge the participation of Indigenous people, particularly Māori. Here, I will answer the second research question, RQ2.

Chapter 4 presents the results and discussion on the case studies conducted for this research. Here, I will answer the third research question, RQ3.

Chapter 5 presents a conclusion of this research, a reflection of the research from a cultural perspective, future work and final remarks. As part of this chapter, I will summarise the answers to the research questions.

2 Māori and Indigenous Approaches to Software Development

In this chapter, I address the first research question, RQ1:

How are Māori cultural methods relevant for software development?

To answer this question, a background of the related work was carried out. In the following sections, Tikanga Māori (Section 2.2) and Approaches to Māori & Indigenous Software Developments (Section 2.3) are presented. Lastly, I summarise the chapter and report the answer to research question 1 (Section 2.4). Next, the background of Kaupapa Māori Research (Section 2.1) is discussed.

2.1 Kaupapa Māori Research

In Chapter 1, I mention that KMR influences the co-design of software and provide an outline of the methodology process. Here, I describe the methodology and emergence of KMR, the beneficiaries of KMR, the positioning of Māori roles within the research process, and the cultural aspirations and practices that shape the research.

Kaupapa Māori Research (KMR) is a methodology that prioritises Māori knowledge, cultural values, and well-being. It is a process that emphasises Māori self-determination and the validity of Māori perspectives in research. Therefore, research is conducted by, with, and for Māori, and incorporates Tikanga Māori (Māori cultural methods). Smith (2015) discusses the KMR process in detail. She acknowledges a set of questions that are inherent to the five principles that underpin research involving Māori people. The eight questions are (1) what research do we want to carry out?, (2) who is the research for?, (3) what difference will it make?, (4) who will carry out this research?, (5) how do we want the research to be done?, (6) how will we know it is a worthwhile piece of research?, (7) who will own the research?, and (8) who will benefit?. The five principles are (1) Whakapapa - genealogy, (2) Te Reo Māori – the Māori language, (3) Tikanga Māori - Māori cultural methods, (4) Rangatiratanga, and (5) Mana Wahine | Mana Tane (pp. 48-49).

The philosophy of Kaupapa Māori Research (KMR) developed during the ethnic revitalisation movement in Aotearoa New Zealand, following the rapid urbanisation of Māori communities after World War II. By the early 1990s, Māori culture had been revitalised, adopting a philosophical and educational stance (Bishop, 1999). However,

Bishop (1999) argued that non-Māori researchers in Aotearoa created research traditions that perpetuated colonial values, leading to a lack of appreciation for Māori knowledge and learning practices. He noted that Māori are concerned with the researcher's accountability, control over the research process, and the knowledge produced, especially regarding who benefits from the research.

As an Indigenous approach, Kaupapa Māori Research (KMR) challenges the dominance of Westernised research (Bishop, 1999). Decolonising and transformative (Pihama, 2010; Brewer, Harwood, McCann, Crengle & Worrall, 2014), KMR encompasses a privileging of Māori knowledge and affects changes that will benefit Māori (Smith, 2012; Pihama, 2010). Kaupapa Māori Research derives from Tangata Whenua (Māori people), whānau (family and extended family), hapū (sub-tribe) and iwi (tribe) and is undertaken by Māori, for Māori and with Māori (Smith, 2015).

Cunningham (2000) clarifies that Kaupapa Māori Research is like "Māori-centred research", such that the participation of Māori at all levels within the research process is predominant. Māori involvement as participants, researchers, and analysts will lead to exclusively Māori research teams. Māori data may be collected using a range of contemporary research tools and applying Māori analysis will result in Māori knowledge (p. 65). Consequently, Māori hui (meetings), waiata (song), and karakia (blessing) are employed, with much of the research undertaken in Te Reo Māori. Bishop (1999) states that Māori cultural aspirations, understandings, and practices shape the research process. Elder (2013) utilises marae wānanga (workshop at a Māori meeting ground) as a data collection process in her Te Waka Oranga research study. She identified that inviting discussion about mokopuna (infants, children, adolescents, young) was most appropriate via marae wānanga.

Essentially, the following methods comprise a Māori approach to research:

- enveloping a research project in Tikanga (Māori cultural methods),
- utilising Māori environments such as locations and buildings, marae (Māori meeting ground), wharenui (traditional meeting house), wharekai (dining hall),
- performing karakia to start and end a meeting/gathering and
- involving Māori iwi and communities, Tangata Whenua, whānau and extended, as well as friends, etc.

I note that Māori cultural methods are at the heart of Kaupapa Māori Research (KMR) and research involving Māori people. I discuss what will produce Māori knowledge with more robust methods. Therefore, “the provision of Māori knowledge, through a Māori controlled research process, has significant potential to support Māori development initiatives” (Cunningham, 2000, p. 67). Barnes (2000) acknowledges there is more than one way of doing things as a researcher or a Māori research group. She made a compelling discovery that to provide high-quality research, her team did not ascribe to one methodology but employed different methods appropriate to their research needs and purposes.

In the context of this research, I employ Kaupapa Māori Research (KMR) philosophy as an underlying foundation for this research which is underpinned by Tikanga Māori and discussed in the next section.

2.2 Tikanga Māori

In this research, I understand Tikanga Māori to be the cultural methods and customary practices of Māori people. A cultural method or practice refers to a unique way of doing things, particularly among Indigenous groups (Drawson, Toombs & Mushquash, 2017; Taani, 2022). For example, Māori engage in karakia (blessing) and whanaungatanga (building relationships). While there are similarities among different Indigenous cultures, many aspects remain distinct. Māori and Pasifika cultures prioritise family as their top cultural value, yet each has a unique perspective on spirituality and religion (Te Morenga et al., 2018).

Tikanga Māori (Māori cultural methods) encompasses values and practices derived from Mātauranga Māori, which is Māori knowledge. The word “Tikanga” comes from the Māori term *tika*, meaning right or correct, indicating the proper way to do something (Mead, 2016). Tikanga emphasises respecting cultural practices and behaving appropriately. There are many Māori customs and behaviours that underpin Tikanga. For instance, touching someone’s head without permission is considered disrespectful, as the head, in Māori culture, is *tapu* or sacred. Similarly, sitting on tables is discouraged due to hygiene concerns and the belief that food is kept separate from bodily waste.

Principles of Tikanga Māori

There are four principles of Tikanga (Māori cultural methods) that guide the case studies, as discussed in Chapter 4: Whakawhanaungatanga, Manaakitanga, Kaitiakitanga and Rangatiratanga.

Whakawhanaungatanga emphasises the importance of creating and maintaining relationships, highlighting the value of familial ties and community bonds. For example, the research supervisors connect the researcher with the teams with whom they already have established relationships. After the initial connections, the researcher and participants actively engage in whanaungatanga (building relationships) or getting to know each other. The researcher organised regular interactions to strengthen these team connections, fostering open communication and trust. By sharing experiences, valuing contributions, and showing genuine interest in the wellbeing of team members, the researcher sought to create a supportive environment conducive to collaborative efforts. This approach deepened understanding and reinforced a sense of belonging among all participants. Additionally, fostering and maintaining strong relationships is essential for the wellbeing of Māori.

Manaakitanga is the process of showing respect, generosity and care for others and can be expressed through the responsibility to provide hospitality and protection to whānau (family and extended family), iwi, the community and the environment (Whaanga, Keegan & Apperley, 2017). I pay attention to this principle when engaging with the participants in the case studies (discussed in Chapter 4). Sharing kai (food) after each hui (meeting) was a meaningful way to end and reflect on the kōrero (discussion) of each session and engage with the case study participants on a casual level. Māori tikanga surrounding kai emphasises the principles of noa (common, ordinary) and tapu (sacred, restricted). Generally, kai is consumed after formalities, particularly at tangihanga (funeral gatherings). The act of eating and sharing kai helps to lift the tapu status of guests, returning them to a state of noa. Additionally, being careful not to interrupt participants while they are speaking is another expression of manaaki (respect).

Kaitiakitanga refers to the concept of guardianship, explicitly protecting the environment. In the context of this research, I define Kaitiakitanga as preserving the data I gather during the interview process (discussed in Chapter 4). The kaitiaki

(guardian), in this instance, the researcher, ensures the data is an accurate account of the information collected and is stored safely. The write-up of the information respects the participants and accurately reflects their contribution.

Rangatiratanga is the Māori term defined as self-determination, sovereignty, autonomy, and the right to exercise authority. In the context of this research, I clarify Rangatiratanga as managing the process surrounding the case studies (discussed in Chapter 4) and how to act in adversity and manage potential conflicts with or between study participants. I also embrace Ahurutanga (warmth and comfort), another Māori principle that is important for creating a safe space.

During the case study engagement process (discussed in Chapter 4) and together with the four principles of Tikanga (Māori cultural methods), I take guidance in the seven cultural values that make up the Values of Research Conduct (VRC): (1) Aroha ki te tangata - Respect the people, (2) He kanohi kitea - Meet face-to-face, (3) Titiro, whakarongo … korero - Look, listen … speak, (4) Manaaki ki te tangata - Serve the people, (5) Kia tūpato - Be cautious, (6) Kaua e takahia te mana o te tangata - Do not trample over the mana of the people, (7) Kaua e māhaki - Do not flaunt your knowledge. This approach informs the practice of researchers (non- and Indigenous) who wish to work with and for Indigenous communities and those studying different fields of study simultaneously and to help researchers create their own interstitial spaces and promote collaboration (Cram & Phillips, 2012).

2.3 Approaches to Māori & Indigenous Software Development

In this section, I explore software applications and consider the processes involved in each apps' development. While computer science is the primary focus, there is a plethora of health interventions and applications available today. Therefore, I consider these a main source for the exploration and present an overview of health applications developed for Māori and Indigenous communities. The following section describes two apps developed for Indigenous communities while the next section describes two apps developed by Māori researchers and developers.

Māori apps

When discussing Māori health, the literature often negatively overrepresents Māori people. Māori usually experience poorer health outcomes and feel marginalised in healthcare settings as most Western healthcare models fail to meet their needs. However, development initiatives like Te Waka Oranga (Elder, 2013), a paper-based (non-digital) intervention shows that creating new healthcare models to accommodate and increase positive Māori outcomes is evidential. Here, I explore two digital apps: (1) Maumahara Papahou, an app derived from a traditional Māori mnemonic aid for Traumatic Brain Injury (TBI) survivors to potentially retain and recall information, (2) OL@-OR@, an app created for Māori and Pasifika people to drive healthy behaviour changes and improve well-being.

Maumahara Papahou is a mobile app prototype created by Taia, Hinze, and Vanderschantz (2018). The authors explored traditional Māori mnemonic aids, focusing on one used by Māori orators to aid in retaining and recalling information. They describe simulating a Māori rākau whakapapa (orator's mnemonic genealogical staff) in their app. Maumahara means “memory” and Papahou means “treasure box”; thus, a “memory treasure box”, as shown in Figure 1.

A rākau whakapapa is a wooden staff with lineally arranged notches. Each notch reminds the orator of a Māori genealogical connection in history and triggers a different genealogy for each notch. The orator would recite all genealogies. The authors considered the 'notches' as a design concept for their app. Taia et al. (2018) based their app on Mixed Reality (MR). MR is a view of the real or physical world - with an overlay of digital elements where physical and digital elements can interact. The memory treasure box contains 3D objects (resembling the notches of a rākau whakapapa), such as a rei puta (whale tooth pendant), or a marble, etc. Embedding objects with the memories of users is done with the help of family and friends who knew the survivor before their injury. When a user sees an object, they should recall the memory associated with that object or memorise that memory by reading about it after clicking the object.

The idea of using a Māori mnemonic aid as a design concept for an app aimed at helping Traumatic Brain Injury (TBI) survivors recall and retain memories from before their injury is ambitious. Additionally, using objects as visual cues opens the door for

further research into other cue types, such as auditory cues, which could benefit survivors with physical impairments, including blindness. Moreover, allowing users to design and customise their object cues would further enhance the users' usability.

Figure 1. *Maumahara Papahou - Memory Treasure Box*

Note. From *An AR Memory App based on Māori Mnemonic Aids* (p. 3), by Taia et al., 2018.

While this approach offers a unique method for assisting TBI survivors in memory recall and retention, the effectiveness of the design concept in terms of cognitive training remains uncertain. The prototype underwent an expert evaluation, however, comprehensive testing to assess the system's effectiveness and its ability to meet user needs is yet to be published.

OL@-OR@ app was developed by Te Morenga, Pekepo, Corrigan, Matoe, Mules, Goodwin and Ni Mhurchu (2018) to promote healthy behaviour changes and enhance well-being for Māori and Pasifika end-users. Both populations share similar values, such as the importance of family. However, spirituality and religious beliefs vary between these two cultures. Colonisation and missionary movements introduced various religious beliefs, including Catholicism and Christianity, to Māori [circa 1814] and Pasifika [circa 1521] populations (Beattie & Stenhouse, 2007; Ernst & Anisi, 2016; Garrett, 1982). While Christianity and cultural traditions from different Pacific Islands continue to shape Pasifika religion, Māori religion, centres around Io (the Supreme Creator) and atua (Māori gods), as well as the belief in the interconnectedness of the

natural and supernatural worlds (Gudgeon, 1905). There is no direct Māori word for “religion”, however, the term whakapono, meaning faith, belief, or trust, is the closest concept introduced by missionaries (Andersen, 1940). Despite these influences, Māori and Pasifika spirituality emphasises strong connections to the land, ancestors and community. Because of this diversity, creating two user interfaces, as shown in Figure 2, in a parallel process was relevant to maintaining autonomy and self-determination for each community.

This culturally tailored app was designed using the integration of Kaupapa Māori Research (KMR) and Co-design methods (Te Morenga et al., 2018; Verbiest et al., 2019). The co-design method is highly compatible with KMR, as it prioritises the needs and views of end-users. A core principle of co-design, as discussed by these authors, is the collaborative partnership between researchers and participants from the Māori community, emphasising the need for relationships. Whilst timeframe and funding challenges caused some tension in the partnership, the “Principles of engagement” (Te Morenga et al., 2018, p. 92) helped resolve any conflict issues, and both sides were made aware of the potential impacts of the restrictions and were encouraged to move forward together.

Figure 2. *OL@-OR@ app*

Note. From *Using codesign to develop a culturally tailored, behaviour change mHealth intervention for indigenous and other priority communities: A case study in New Zealand* (p. 15), by Verbiest et al., 2019.

The co-design methods included generative data collection, metaphors, storytelling, reflection and sharing. These methods enabled the researchers to gain a deeper understanding of their participants' lives and aspirations, which would not otherwise emerge through traditional methods such as interviews and observations. The community researcher gathered the information through photographs, audio recordings, and reflections from community members.

The project team included non-Māori, Māori and Pasifika researchers and community health providers across the North Island of Aotearoa New Zealand. A Māori health promotion provider initiated the Māori engagement process, while two Pasifika organisations initiated the Pasifika engagement process (Te Morenga et al., 2018). The need to educate their research team in Kaupapa Māori Research (KMR) protocols and values was identified and implemented during the development of the OL@-OR@ app.

Other Indigenous apps

Indigenous and First Nations people have long endured negative outcomes from poor health systems or of those that fail to meet their needs (Robbins, Gouse, Brown, Ehlers, Scott, Leu & Joska, 2018). The lack of cooperation and coordination from government bodies has impacted health care delivery resulting in the overlap and provision of healthcare services. However, access of mobile and ICT technology for these populations, particularly remote and rural communities is providing relief by alleviating poverty and/or improving their socio-economic status (Siew, Yeo & Zaman, 2013). Here, I explore two digital apps: (1) Hep B Story, an app created for Indigenous Australians to improve their knowledge about Hepatitis B, and (4) NeuroScreen, an app created for an HIV population group in South Africa that uses cognitive tests to examine the neuropsychological domains.

Hep B Story is a culturally appropriate bilingual app produced by Davies et al. (2015). The app provides educational information to improve knowledge about Hepatitis B for Indigenous Australians (from Arnhem land) living with this chronic condition. The initial evaluation resulted in statistically significant improvement in Hep B-related knowledge and positive opinions regarding the app's acceptability, ease of use, and recommendation to others. During Phase 1 of the development process for the Hep B Story app (Davies, Bukulatjpi, Sharma, Davis & Johnston, 2014), the authors identified

design issues regarding ethnic, gender and cultural misappropriation. To address these issues, the authors looked at making gender-neutral avatars, ethnically neutral skin colour (i.e. blue, not brown), and replacing the fruit images with text over liver images. After addressing design issues, the app gained significant popularity.

While history reports the segregation and denial of Indigenous languages, many of these languages have not yet developed the vocabulary needed to describe modern concepts and items. Davies et al. (2015) plans to develop the Hep B Story app using one of the languages from the Yolngu Matha collection of Arnhem Land Australia, in addition to providing an option to use English. The developers and speakers involved in the Hep B project worked together to interpret the collection and create definitions for terms that align with contemporary language use. This effort is a crucial aspect of software development with First Nations.[2]

In Phase 2, Davies et al. (2015) implemented the Participatory Action Research (PAR) framework, which incorporated ongoing consultation and evaluation with the community throughout each iterative cycle. The stages included “the development of the storyboard, the translation process (forward translation and back translation), a prelaunch community review, launch and initial community evaluation, ending with a wider launch and assessment at a viral hepatitis conference” (p. 1). The conclusion of Phase 2 resulted in the development of the “Hep B Story” app, which is now available for download on Apple devices via the Apple App Store, on Android devices through the Google Play Store, and as a web-based app on the Menzies School of Health Research website.

NeuroScreen is a health app that screens for Neurocognitive impairment (NCI), otherwise known as HIV-associated neurocognitive disorder (HAND). HAND is recognised as a common sequela of HIV. In South Africa (RSA), an estimated 23% to 76% of the 7 billion people living with HIV (PLHIV) will suffer from NCI-related disorders such as mental processing speed, etc. (Grant, 2008; Robbins et al., 2018).

Robbins et al. (2018) recognised a gap in the care of PLHIV and observed the need to improve health outcomes by detecting early signs of NCI. These authors adapted the NeuroScreen mobile app (Robbins, Brown, Ehlers, Joska, Thomas, Burgess, Byrd

[2] I would like to thank the Thesis examiners for alerting me to this concept.

& Morgello, 2014) to run on a 7-inch Google Nexus tablet, which offers a sufficiently larger display and provides touchscreen capabilities that enhance the automation of neuropsychological testing. It includes a variety of tests that assess neurocognitive domains of verbal learning, memory, processing speed, attention and concentration, as well as executive and motor functioning. Most of the test instructions are presented in an audio-visual format, making them suitable for populations with low literacy levels.

Lay Health Workers (LHWs) play a vital role as frontline service providers, acting as a bridge between formal healthcare systems (Schneider & Lehmann, 2010). They do not need formal qualifications or professional assistance to administer the NeuroScreen app, even in areas with limited internet connectivity. So long as the app is installed on a mobile device, such as a tablet, LHWs can access it anytime and anywhere, regardless of their internet connection. The app does not seek to replace gold-standard neuropsychological assessments but is rather a step toward transforming clinical practice using mobile technology where a better referral, tracking and integration with electronic medical records is achieved.

To improve health outcomes for Neurocognitive impairment (NCI) for people living with HIV in the Western Cape region of South Africa, Robbins et al. (2018) adapted their NeuroScreen app for use in either English or isiXhosa, the Bantu language predominantly spoken where they conducted the study. Forward and backward language translation methods were employed, with assistance from bilingual researchers who were fluent in both English and isiXhosa. Additionally, Robbins et al. (2018) refined the isiXhosa translations to adhere to colloquial language conventions. They recorded the audio files with a native isiXhosa speaker for the audio-visual instructions. Despite efforts to provide the app in a local dialect, many of the participants opted to take NeuroScreen in English. These authors acknowledge that further research is needed to understand this discrepancy.

The NeuroScreen study identified further limitations, (1) a small sample of PLHIV with mostly female participants, (2) a formal assessment of language fluency for either English or isiXhosa was not conducted, (3) the study detected NCI that may or may not be a result of HIV, (4) there is no established performance data for NeuroScreen among isiXhosa-speaking South Africans or other language groups in South Africa. As a result, it is not appropriate to generalise the results from this test. (5) The gold

standard battery (a comprehensive evaluation of cognitive functions) included several tests that measured areas not covered by NeuroScreen, such as verbal fluency and perseveration. Whereas NeuroScreen only focused on areas regarding HIV. Furthermore, NeuroScreen is not meant to be a substitute for comprehensive neuropsychological assessment.

2.4 Summary

In this chapter, I summarise the research on Māori and Indigenous approaches to software development and present the answer to the first research question, RQ1:

How are Māori cultural methods relevant for software development?

Kaupapa Māori Research (KMR) and Tikanga Māori (Māori cultural methods) are relevant for software development. These approaches incorporate Mātauranga Māori (Māori knowledge) within the research and development process. They significantly support development initiatives aimed at benefiting Māori people. Māori cultural aspirations, understandings, and practices influence the research process and facilitate the building and maintenance of relationships.

An integrated KMR Co-design process will ensure researchers and developers of software applications, especially those developed by, for and with Māori and/or other Indigenous people, meet the needs and views of end-users, establish collaborative partnerships between the researchers and participants and resolve conflict issues by engaging in principles, such as Tikanga Māori.

Other design approaches and cultural requirements to consider, which are relevant for both Māori and Indigenous software development, include:

- the conceptual use of traditional cultural artifacts to shape innovation,
- technological considerations (e.g. tablets for larger screen display, limited or no internet connectivity),
- visual and audio features (e.g. ethnically neutral-skin colour (i.e. blue, not brown), toggle English and local dialect, audio-visual instruction), and
- research and development teams to be educated in Māori and/or other Indigenous cultural methods.

3 Māori participation in the Software Development Process

While there is much discussion regarding Indigenous and First Nations people, and technology, particularly in significant works such as Information Technology and Indigenous Communities (Ormond-Parker, Corn, Fforde, Obata & O'Sullivan, 2013) and Indigenous People and Mobile Technologies (Dyson, Grant & Hendriks, 2015),[3] this research specifically focuses on the participation of Tangata Whenua (Māori people), in the process stages of developing software.

In this chapter, I address the second research question, RQ2:

How are Māori people acknowledged in software development processes?

To answer this question, a background and review of the literature was carried out. In the following section, a systematic literature review (Section 3.2) is presented. Lastly, I conclude the chapter and report the answer to research question 2 (Section 3.3). Next, a background on general users in software development processes (Section 3.1) is presented.

3.1 Background: General users in Software Development processes

In this section, I present an overview of the established Software Development (SD) processes discussed in the literature. I particularly examined the processes regarding general user participation.

Method

My aim was to explore user participation discussed in standard texts for Software Engineering. For this purpose, I consulted with software engineering academic staff at the local university and examined the university's *Catalogue of Papers* (CoP) to identify standard texts.

Results

Initially, 74 texts were selected, as shown in Table 1, with 3 of them recommended by the university staff and a further 71 texts from the CoP. Over 50% were excluded due to duplicates, such as a text offered across multiple qualifications and course papers. Others were removed because they did not meet inclusion criteria, these included text

[3] I would like to thank the Thesis examiners for alerting me to these works.

for programming (coding), machine learning, systems analysis and design, and more. Additionally, I excluded 32 texts because they did not describe a software development process.

Table 1. *University texts selected for final analysis*

Sources / Sets	University		TOTAL
	Staff	CoP	
Initial	3	71	**74**
Papers excluded after applying inclusion/exclusion criteria.	0	38	**38**
Pilot	3	33	**36**
Papers excluded after reading paper sections, intro, method, etc.	0	32	**32**
Primary	3	1	**4**

The four university texts inform software engineering class lectures and course readings, and each one discusses different types of software models in detail. I present the analysis of these models below.

Overview of software development processes

Here, I present an analysis of traditional Software Development processes. The Waterfall model, a sequential linear process, is one of the earliest traditional models mentioned in each of the texts. Several Agile methods were also mentioned, such as Scrum, Feature-Driven Development (FDD), and Rapid Application Development (RAD), among others. These agile methods are similarly based on incremental development and delivery (Sommerville, 2011). The eXtreme Programming (XP) model is the most widely used and will therefore represent Agile methods, as shown in Table 2.

Table 2. *Software development processes identified in the texts*

Text / SD Process	*Bourque, P., & Fairley, R. E. (2014).*	*Sommerville, I. (2011).*	*Robbins, S. (2011).*	*Fairley, R. E. (2011).*
Waterfall	✓	✓	✓	✓
Incremental/ Iterative	✓	✓	x	✓
Spiral	✓	✓	x	✓

SDLC[4]	✓	✓	✓	x
XP[5] **(Agile)**	✓	✓	x	x
Evolutionary	x	x	x	✓
Rational Unified Process	x	✓	x	x
Requirements Engineering Process	x	✓	x	x
Reuse-Oriented Software Engineering	x	✓	x	x
V & V[6]	x	✓	x	x

After analysing the processes, Sommerville (2011) was the one text that presented nine of the 10 models. In his book, I identified four basic activities: specification, development, validation, and evolution (p. 36). Of the four activities, Table 3 presents a 6-phase colour model. (1) Specification = Plan, (2) Development = Design & Develop, (3) Validation = Evaluate, (4) Evolution = Release & Maintain.

Table 3. *The 6-phase colour model*

Phase	Name	Description
A	**Plan** *orange*	The need or opportunity is identified, and a plan is created, along with the elicitation and analysis of user requirements. (Matkovic & Tumbas, 2010; Sommerville, 2011).
B	**Design** yellow	The components, interfaces, and other features for the software are defined (Bourque & Fairley, 2014), and the requirements are transformed into a complete design for the software (Matkovic & Tumbas, 2010).
C	**Develop** green	The design requirements are converted into a complete software product, and are implemented, tested, and refined (Matkovic & Tumbas, 2010).
D	**Evaluate** blue	The software is evaluated with the help of users, to check if the product conforms to requirements, and meets the needs of the customer (Sommerville, 2011).
E	**Release** purple	The software is launched and distributed to the customer (Sommerville, 2011). Demonstrations of the product and validation that the system is operational usually occurs here.
F	**Maintain** magenta	This activity involves ongoing software maintenance and updates, and in-process reviews (Bourque & Fairley, 2014; Matkovic & Tumbas, 2010).

The 6-phase colour model will be used to represent each model in the same manner. This will help to identify, if at all, which steps in each model present user participation.

[4] SDLC - Software Development Life Cycle
[5] XP - eXtreme Programming
[6] V & V - Verification & Validation

This will be made evident via the next two tables. In Table 4, I use the colours of the 6-phase model to distinguish the individual steps from each other by mapping each models' steps with the six phases. For example, the Incremental/Iterative model, the second model in Table 4 has 10 steps:

A. Steps 1, and 2 map to the Plan phase (orange),
B. Step 3 maps to the Design phase (yellow),
C. Steps 4, 5, 6, and 7 map to the Develop phase (green),
D. Step 8 maps to the Evaluate phase (blue), and
E. Steps 9 & 10 are represented by the Release phase (purple).
F. No steps map to the Maintain phase (magenta).

Table 4. *Mapping steps of the 10 Software Development processes via the 6-phase colour model*

Process | Step	1	2	3	4	5	6	7	8	9	10
Waterfall	Requirements definition	System & Soft. Design	Implementation	Unit testing	Integration	System testing	Operation	Maintenance		
Incremental/ Iterative	User needs, cust. exp, acquirer conditions	Document Operational	Specify hardware/software platform	Develop Soft. Reqs	Design Soft. Architecture	Partition the design	Build, integrate; Demo cap.	Software verification	Operational validation	Demo versions
Spiral	Determine obj., alter., and constraints	Evaluate alter., Identify and resolve risks	Develop, verify next-level product	Plan next phase						
SDLC[7]	Plan	Design	Build	Test	Launch					
XP[8]	Select user stories for this release	Break down stories to tasks	Plan release	Develop software	Integrate software	Test software	Release software	Evaluate system		
Evolutionary	User needs, cust. exp, acquirer conditions	Evolve operational requirements	Evolve software requirements	Design Software	Obtain software components	Integrate software components	Verify & Validate Software	Demo product		
RUP[9]	Inception	Elaboration	Construction	Transition						
REP[10]	Feasibility	Elicitation	Specification	Validation						
R-OSE[11]	Requirements specs	Component analysis	Requirements modification	System design with reuse	Development and Integration	System validation				
V & V[12]	Analysis	Evaluation	Review	Inspection	Assessment	Testing				

[7] SDLC - Software Development Life Cycle
[8] XP - eXtreme Programming
[9] RUP - Rational Unified Process
[10] REP - Requirements Engineering Process
[11] R-OSE - Reuse-Oriented Software Engineering
[12] V & V - Verification & Validation

The Waterfall model, one of the earliest processes used in managing large software developments (Royce, 1987), is presented in the literature (Sommerville, 2011) as having combined steps. Steps 3 and 4 of the Waterfall model in Table 4 are one process (Implementation and Unit testing). The same goes for Steps 5 and 6 (Integration and System testing), and 7 and 8 (Operation & Maintenance). Consequently, these steps present distinct activities and are separated into individual steps in the table, which helps to understand the single processes in each model and the possible indication of user participation.

Steps 4, 5, and 6 of the XP model are also typically introduced in the literature as one process. But they are distinct activities and therefore we look at them separately.

The V&V model in Table 4, is presented as separate activities as it is described in the literature (Sommerville, 2011). The term “Analysis” is synonymous with the requirements analysis phase and therefore maps to the Plan phase (A - orange). However, the last 5 steps of the V&V model are terms that are synonymous with each other and for that reason they would be simplified into one step, the Evaluate phase (D - blue). Therefore, the V&V model would be seen as having two phases: A and D.

Although some processes, such as Incremental/Iterative, Spiral, and XP (Agile), involve repeating or cycling back through steps, they are presented sequentially in Table 4. Despite being the most linear of all the models and not expecting iteration, the Waterfall model shows that the Evaluate phase (D) occurs twice (Steps 4 & 6). We denote the practicality of implementing a design, *testing it*, integrating it into the working environment, and then *testing it* again.

The colour mapping in Table 4 shows that the models focus on defining, eliciting, and analysing user requirements, evaluating alternatives, identifying risks, and documenting and developing the software. There is less emphasis on maintenance. In addition, the mapping indicates that the 6-phase colour model closely aligns with the traditional software development life cycle (SDLC).

After mapping the steps of each of the models found in the university texts, I further analysed them to identify user participation and map this via the 6-phase colour model, as denoted in Table 5 in the next section.

Summary of general user participation in software development

Here, I summarise the results of the analysis for general user participation indicative to the software development processes previously shown in Table 4. Table 5 indicates that the Rational Unified Process and the Reuse-Oriented Software Engineering models do not involve user participation. Additionally, there is no indication of user participation in the Release, or Maintenance phases within each model.

However, user participation is evident in the Evaluate phase in eight of the models, and six of those eight models show user participation in the Plan phase, while the Incremental/Iterative and Spiral models do not. In Incremental development, an initial implementation is created and then user feedback is solicited (Bourque & Fairley, 2014; Sommerville, 2011). The Spiral model acknowledges and evaluates risk management during the first phase. Although user participation may pose a risk, it is unlikely that users are involved in the Planning activity of these models.

Table 5. *General user participation in SD processes*

Phase / Process model	Plan		Design		Develop		Evaluate		Release		Maintain	
	G	I	G	I	G	I	G	I	G	I	G	I
Waterfall	✓	x	x	x	x	x	✓	x	x	x	x	x
Incremental/Iterative	x	x	x	x	x	x	✓	x	x	x		
Spiral	x	x	x	x	x	x	✓	x				
SDLC	✓	x	x	x	x	x	✓	x	x	x		
XP	✓	x	✓	x	✓	x	✓	x	x	x		
Evolutionary	✓	x	x	x	x	x	✓	x	x	x		
Rational Unified Process	x	x	x	x	x	x			x	x		
Requirements Engineering Process	✓	x	x	x			✓	x				
Reuse-Oriented Software Engineering	x	x	x	x	x	x	x	x				
Verification & Validation	✓	x					✓	x				

Note. **G**=General user participation. **I**=Indigenous user participation. ✓ = yes. x = no.

In most software projects, users typically provide input and feedback on the planning and testing of the software but are not usually involved in actual coding. However, the XP model includes users in the Design and Develop phases, as shown in Table 5.

According to Bourque and Fairley (2014, p. 171), there is direct customer involvement on the team (typically defining acceptance tests). Sommerville (2011) explains that in Extreme Programming, “user priorities and the elicitation of requirements comes from the users who are *part of the development team*” (p. 38) and "a customer representative takes part in the development" (p. 65), and in the context of this research, a customer is considered a user, as defined in Section 1.2. This makes the XP model unique in involving users in the design and development phases.

Furthermore, the literature should clearly identify the types of users involved in the process. As I have indicated in Table 5, none of the process models acknowledge the participation of Indigenous or Māori people. These models are mainly used to teach software engineering and do not detail user participation, particularly for Indigenous communities. In contrast, the publications found through searches and snowballing have different insights that I will discuss further in Section 3.2.

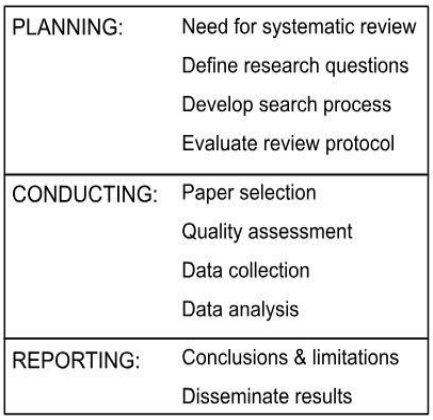
3.2 SLR: Indigenous users in Software Development processes

In this section, I present the exploration of the software development processes that present Indigenous user participation in the literature. I particularly focus on the participation of Tangata Whenua (Māori people).

Method

I used a Systematic Literature Review (SLR) and followed the three-phase process, as shown in Figure 3. Next, I will outline the steps in the first phase of the SLR (Planning).

Figure 3. *A process for Systematic Literature Review (SLR)*



Note. From *Procedures for Performing Systematic Reviews* (p. 3), by Kitchenham, 2004.

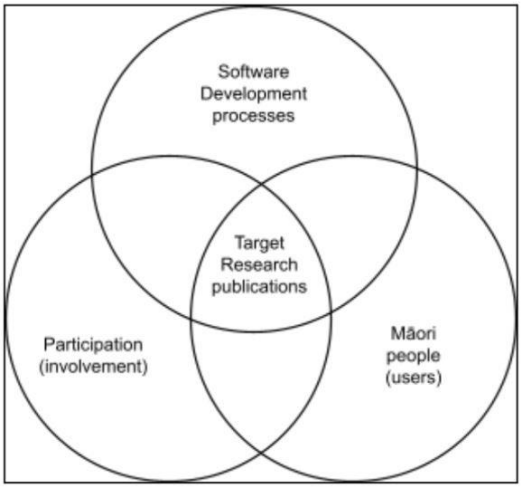
The SLR begins with the **Planning** phase, which has four steps: (1) identifying the need for review, (2) defining the research questions, (3) developing a search strategy, and (4) evaluating the review protocol. As argued in the Introduction chapter, *software development* is a Westernised process, and the lack of published research discussing Indigenous and Māori design processes for software development leaves a significant gap in our understanding. Therefore, a systematic review of the literature is required.

Here, I address RQ2:

How are Māori people acknowledged in software development processes?

For this SLR, the search process aims to identify the target research publications, as shown in Figure 4.

Figure 4. *SLR Target research publications and main topics*



Note. Author's own image.

To guide the search, I used the PICO worksheet & Search Strategy Protocol (Miller, 2001) to determine the research questions, topics, terms, and search queries (see Appendix B). Table 6 shows the search terms and query combinations used in the search for relevant papers. I group the software development processes into two categories: traditional and contemporary. A traditional process is one that follows a linear or sequential methodology, such as the Waterfall method. In contrast, a contemporary process is one that follows an iterative or adaptable methodology, such as an Agile method.

Table 6. *Search terms and query combinations*

Main topic	**Search terms & synonyms**	**Search string query combinations (includes Boolean operators & wildcards)**
Software Development process*/es/ing	method*/s/ology model*/s/ling life cycle*/s life-cycle*/s	1. (software AND development AND process* (software AND development AND process* AND method* AND model* AND life cycle* AND life-cycle* (software AND development AND process* OR method* OR model* OR life cycle* OR life-cycle*
Participation (involvement)	participat*e/ory involve*/d/s/ment	2. AND participation OR participat* AND involve* AND participation OR participat* OR involve*
Māori users	Indigenous user*/s people communit*/y/ies cultur*/e/al	3. AND Māori AND Indigenous AND user* AND people AND Māori OR Indigenous AND user* AND people AND Māori OR Indigenous AND user* OR people AND Māori AND Indigenous AND user* AND people AND communit* AND cultur* AND Māori OR Indigenous AND user* AND people AND communit* AND cultur* AND Māori OR Indigenous AND user* OR people OR communit* AND cultur*
Category	traditional contemporary *none*	4. AND traditional AND contemporary) AND traditional OR contemporary))

Note. The asterisk or * is a wildcard used to broaden the search by finding words starting with the same letters.

Each search string includes a query combination from each topic, such as:

([1]software AND development AND process* [2]AND participation OR participat* AND involv* [3]AND Māori AND Indigenous AND user* AND people [4]AND traditional OR contemporary)

An evaluation of the review process ensures the validity and effectiveness of the research method. Therefore, the review protocol involved ongoing consultation with the research supervisors.

Next, I will outline the steps in the second phase of the SLR (Conducting).
The **Conducting** phase has four steps: (1) selecting the papers for review, (2) assessing the quality of the selected papers, (3) collecting the data, and then (4) analysing the data.

I selected papers for the Systematic Literature Review (SLR) by consulting software engineering academic *staff* at the local university and examining the university's *Catalogue of Papers* (CoP). This process helped me identify standard textbooks and useful readings. To conduct a comprehensive review, I utilised online searching and snowballing techniques.

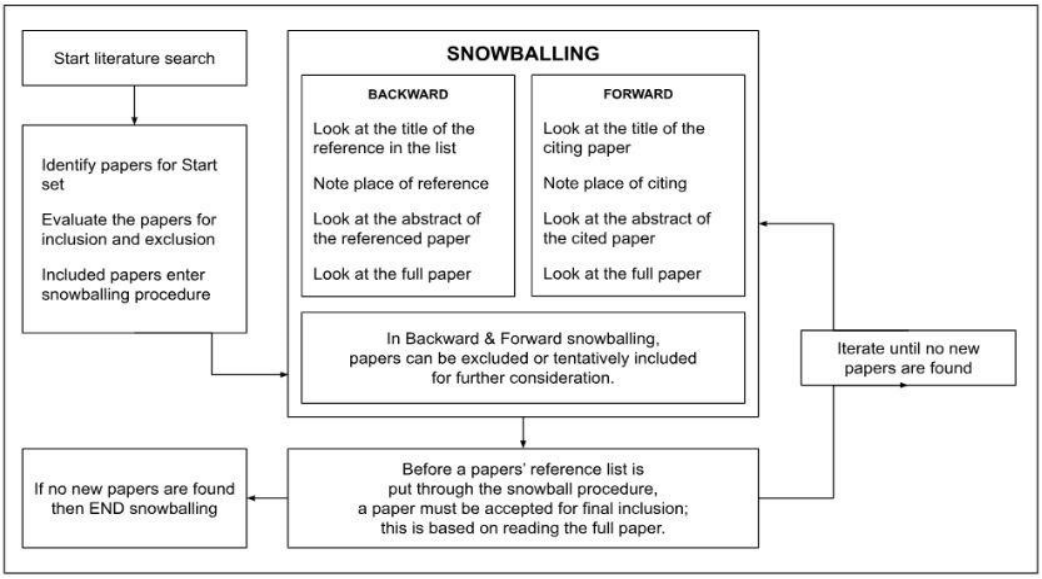
Online searching involved various digital library sources: ACM, Google Scholar, IEEE Xplore and Science Direct. As discussed in detail later, I discovered that participation of Māori people was not acknowledged in any of the software development processes via the *online search* method. Consequently, I employed snowballing to locate relevant papers.

Snowballing has two methods: (1) Backward snowballing uses the reference list of a paper, and (2) Forward snowballing uses citations to a paper. Both methods rely on a set of papers to begin the process. I used the following three papers recommended by the supervisors, as the "start set" for snowballing:

1. Rolleston et al. (2021)
2. Te Morenga et al. (2018)
3. Siew et al. (2013)

Figure 5 illustrates the procedure I followed when conducting the snowballing.

Figure 5. *A Snowballing procedure*



Note. From *Guidelines for Snowballing in Systematic Literature Studies and a Replication in Software Engineering* (p. 4), by Wohlin, 2014.

Additionally, I used a keyword search based on keywords found in the papers resulting from the snowballing procedure. The following keyword strings were searched via Google Scholar to find further papers pertinent to the research question.

1. mHealth Māori
2. “software development” rural
3. indigenous digital game

Results of the search methods are presented below.

Assessing the quality of the papers ensures they are relevant for review. This involved reading titles, abstracts, reference details (authors, years, source), applying inclusion and exclusion criteria, and finally, reading paper sections such as method, conclusion, etc. Also, ongoing consultation with the research supervisors ensured that the review was evaluated well.

The inclusion criteria accepts texts, peer-reviewed articles, journals, and conference proceedings based on the following:

- The paper should be accessible.
- Years ranging from 1983 to 2023, inclusive.
    - The 40-year range presents traditional models such as Royce’s (1987) Waterfall model.

- Research that discusses software development and design processes, including software applications, processes, models, etc.
- Research that presents Indigenous (local, national, and international) software developments written in English and/or Te Reo Māori (Māori language).

The exclusion criteria dismisses texts and studies based on the following:

- Abstract only, 'unevaluated' new idea, patent and/or industry standard, and without empirical results, including dictionaries and vocabulary lists.
- Research that is not related to software development and design or does not answer any of the research questions, such as texts on:
    - Programming;
        - handbooks, guides and/or guidelines
        - languages, i.e. Visual Basic, C, C#, C++, Java, etc.
        - websites, i.e. Tutorialspoint, Stack Overflow, etc.
    - Systems performance, maintenance and testing, etc.

The initial papers selected for review underwent inclusion and exclusion criteria (see Appendix C).

The data collection involved manually collecting and recording the following details from the selected primary papers (see Appendix D). The following data is collected:

1. UID: Unique identifier (includes: first three letters of first author, and year of publication, such as: VER2019 = (Verbiest et al., 2019). *Note:* different papers by the same first author in the same year will be suffixed with a letter, for example: SIE2011a or SIE2011b. Also, data will be ordered where applicable: author alphabetically ascending and year numerically descending.
2. Author: The author(s) and/or affiliation (organisation and country)
3. Title: Title of the paper
4. Year: Year of publication
5. Reference: Full reference of the paper and/or URL/DOI/ISSN/ISBN
6. Discipline: Information Communication Technology (ICT), Health, ICT & Health, and Other
7. Development or Research: Software Application (SAPP), Technologica project, Information Technology Framework (ITFW), Health Framework (HFW), Study (user study or theoretical analysis)

8. Methods used: Kaupapa Māori, Co-design, Participatory Design, Model types, other methods
9. Non- and Indigenous stakeholders: developers, researchers, users
10. Steps in a SD process that indicate Indigenous user participation
11. Steps that extend a SD process to augment Indigenous participation

I analysed the collected data and present the results below as the final phase of an SLR (Reporting), which involves documenting and disseminating the literature review results.

Results

After the search process, the search results initially yielded over 5,000 papers, as indicated in Table 7. The first exclusion round removed approximately 44% of the papers due to duplications and those that did not meet the inclusion criteria, leaving 2,874 papers. Upon closer examination, many of those papers only matched one or two of the following main topics, but not all three: (1) software development processes, (2) participation (involvement), or (3) Māori people (users) and were removed from further analysis.

Table 7. *Number of papers selected for review*

Sources / Sets	Online					Snowball & Keyword			TOTAL
	ACM	GS	IEEE	SD	SL	BSB	FSB	KS	
Initial	297	100	2501	310	100	1418	76	400	**5202**
Papers excluded after applying inclusion/exclusion criteria.	1	1	984	1	0	1341	0	0	**2328**
Pilot	296	99	1517	309	100	77	76	400	**2874**
Papers excluded after reading paper sections, intro, method, etc.	296	98	1517	309	100	68	73	386	**2847**
Primary	0	1	0	0	0	9	3	14	**27**

Further publications were excluded because they discussed the use and efficacy of software applications for Indigenous communities and not the participation and involvement of Indigenous people in the development of those applications. Some publications described behavioural change apps to assist Indigenous people, such as quit smoking and losing weight, and others discussed ICT or WiFi connectivity for

Indigenous communities. Also, some publications were excluded based on specific criteria for relevance. For instance, the term “rural” could refer to a community that is either Indigenous or geographically located. The latter interpretation was considered irrelevant and therefore omitted from analysis. While some papers seemed relevant, none of them addressed the *participation* of Indigenous people, especially Māori, or their communities. In the end, 27 papers made it into the primary set and are listed in Table 8.

Table 8. *SLR primary papers selected for review (n=27)*

UID	**Reference**
HUM2022	Humphrey, G., Chu, J. T., Ruwhiu-Collins, R., Erick-Peleti, S., Dowling, N., Merkouris, S., ... & Bullen, C. (2022). Adapting an evidence-based e-learning cognitive behavioral therapy program into a mobile app for people experiencing gambling-related problems: formative study. JMIR Formative Research, 6(3), e32940.
ALA2021	Alazzam, M. B., Alassery, F., & Almulihi, A. (2021). Development of a mobile application for interaction between patients and doctors in rural populations. Mobile information systems, 2021, 1-8.
MWA2021	Mwangonde, K., Ntinda, M., & Hasheela-Mufeti, V. (2021, May). A Game-based Approach to Revive Cultural Heritage amongst the Youth. In *2021 IST-Africa Conference (IST-Africa)* (pp. 1-8). IEEE.
ROL2021	Rolleston, A. K., Bowen, J., Hinze, A., Korohina, E., & Matamua, R. (2021). Collaboration in research: weaving Kaupapa Māori and computer science. AlterNative: An International Journal of Indigenous Peoples, 17(4), 469-479.
LAP2020	LaPensée, E. (2020). SPEAR: a framework for Indigenous cultural games. ANTARES: Letras e Humanidades, 12(28), 4-22.
SUM2020	Summers, K., Salazar, V., Olszyk, D., Harwell, L., & Brookes, A. (2020). The development of DISC (decision integration for strong communities): An agile software application of sustainability indicators for small and rural communities. Community quality-of-life indicators: Best cases VIII, 89-113.
BEK2019	Bekele, R., Biru, T., Sametinger, J., Groher, I., Floyd, C., & Pomberger, G. (2019). Adapting Ethnography for Design Research: Lessons Learnt from Design of Mobile Systems for Rural Health Care in Ethiopia. In *ICIS*.
LON2019	Longboat, M. (2019). Terra Nova: Enacting Videogame Development through Indigenous-Led Creation (Doctoral dissertation, Concordia University).
VER2019	Verbiest, M. E., Corrigan, C., Dalhousie, S., Firestone, R., Funaki, T., Goodwin, D., ... & Mhurchu, C. N. (2019). Using codesign to develop a culturally tailored, behavior change mHealth intervention for indigenous and other priority communities: A case study in New Zealand. Translational behavioral medicine, 9(4), 720-736.
SIN2018	Singh, R. K., Bisht, D., & Sundriyal, R. C. (2018). Village Information System (VIS): A Step towards Rural Development in the Indian Himalayan Region.

TEM2018	Te Morenga, L., Pekepo, C., Corrigan, C., Matoe, L., Mules, R., Goodwin, D., … Ni Mhurchu, C. (2018). Co-designing an mHealth tool in the New Zealand Maori community with a "Kaupapa Maori" approach. *AlterNative : An International Journal of Indigenous Peoples*, *14*(1), 90–99.
DOB2017	Dobson, R., Whittaker, R., Bartley, H., Connor, A., Chen, R., Ross, M., & McCool, J. (2017). Development of a culturally tailored text message maternal health program: TextMATCH. JMIR mHealth and uHealth, 5(4), e7205.
HOS2017	Hossain, E. D., Juan, S. F. S., Labadin, J., & Agas, P. (2017). Design of a Transcription Tool for the Kelabit Community of Bario, Sarawak. Journal of Telecommunication, Electronic and Computer Engineering (JTEC), 9(3-11), 121-124.
TEK2017	Teka, D., Dittrich, Y., & Kifle, M. (2017, September). Contextualizing user centered design with agile methods in Ethiopia. In 2017 IEEE AFRICON (pp. 911-916). IEEE.
ISA2015	Isabirye, Naomi, Stephen V. Flowerday, Amit Nanavati, and Rossouw Von Solms. "Building Technology Trust in a Rural Agricultural e-Marketplace: A User Requirements Perspective." The Electronic Journal of Information Systems in Developing Countries 70, no. 1 (2015): 1-20.
ZAM2015	Zaman, T., & Kulathuramaiyer, N. (2015). eToro: Appropriating ICTs for the management of Penans' indigenous botanical knowledge. In Indigenous people and mobile technologies (pp. 267-278). Routledge.
YAS2014	Yasir, R., & Ahmed, N. (2014, March). Beetles: A Mobile Application to Detect Crop Disease for Farmers in Rural Area. In presented at the Workshop on Human And Technology (WHAT) (pp. 11-14). Academia.
HUA2013	Huang, C. H., & Huang, Y. T. (2013). An annales school-based serious game creation framework for taiwanese indigenous cultural heritage. *Journal on Computing and Cultural Heritage (JOCCH)*, *6*(2), 1-31.
SIE2013	Siew, S. T., Yeo, A. W., & Zaman, T. (2013). Participatory action research in software development: indigenous knowledge management systems case study. In Human-Computer Interaction. Human-Centred Design Approaches, Methods, Tools, and Environments: 15th International Conference, HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part I 15 (pp. 470-479). Springer Berlin Heidelberg.
SIE2012	Siew, S. T., & Yeo, A. W. (2012, July). Adapting PRISMA for software development in rural areas: A mobile-based healthcare application case study. In 2012 Southeast Asian Network of Ergonomics Societies Conference (SEANES) (pp. 1-6). IEEE.
WHI2012	Whittaker, R., Merry, S., Dorey, E., & Maddison, R. (2012). A development and evaluation process for mHealth interventions: examples from New Zealand. Journal of health communication, 17(sup1), 11-21.
SIE2011	Siew, S. T., & Yeo, A. W. (2011, July). Employing participatory action research to augment software development for rural communities. In Proceedings of HCI 2011 The 25th BCS Conference on Human Computer Interaction. BCS Learning & Development.
SIM2009	Simba, F., Trojer, L., Mvungi, N. H., Mwinyiwiwa, B. M., & Mjema, E. M. (2009). Rural Connectivity technologies cost analysis. International Journal of Information and Communication Engineering, 3(11), 2052-2058.
LEA2007	Leavy, B., Wyeld, T. G., Carroll, J., Gibbons, C., Ledwich, B., & Hills, J. (2007b, September). Improvements to the Standard Torque Game Engine for Australian Indigenous Storytelling: Developing the Digital Songlines Game Engine. In 13th International Conference on Virtual Systems and Multimedia (VSMM'07).

MAN2006	Mann, S., Russell, K., Camp, J., Crook, M., & Wikaira, J. (2006). Maori Game Design. In 19th Annual Conference of the National Advisory Committee on Computing Qualifications, Wellington, New Zealand, NACCQ in cooperation with ACM SIGCSE (pp. 165-174).
CHE2005	Chetty, M. (2005). Developing locally relevant applications for rural South Africa: A telemedicine example.
FLE1989	Fleer, M. (1989). Reflecting indigenous culture in educational software design. Journal of Reading, 32(7), 611-619.

Of the 27 primary papers, 26 were published from 2005 onwards, and a single paper was published in 1989. So, work on software development with Indigenous people only took off after 2005.

Overview of software development projects with Indigenous people

In this section, I discuss the 27 projects of software development involving Indigenous people, as listed in Table 8. Also, I compare and summarise the observations from these projects and discuss how Indigenous people, particularly Māori were acknowledged in the software development process.

Humphrey, Chu, Ruwhiu-Collins, Erick-Peleti, Dowling, Merkouris & Bullen (2022) present their mobile phone app *Manaaki*, a conversion of the GamblingLess web-based intervention that supports Māori facing gambling harm. The authors engaged both domain experts on gambling and end-users from Māori and Pasifika communities to inform the content for the conversion. These authors used a Co-creation method to develop the Manaaki app. The development process had two main steps: (1) creating content with experts and (2) working with end-users. The study identified three user groups: Māori, Pasifika, and young adults aged 18 to 25. Six focus groups were held, with two sessions for each group. The focus sessions were recorded with notes and lasted about sixty to ninety minutes. The data from the focus groups shaped the app's features, functions, and design through prototypes. The research team reported that the co-creation and collaborative approach was highly effective. The end-user groups reported feeling a strong sense of ownership and investment in the app. The authors argue that interventions involving end-users are more likely to be effective than those that do not.

Insights, observations or lessons learned:

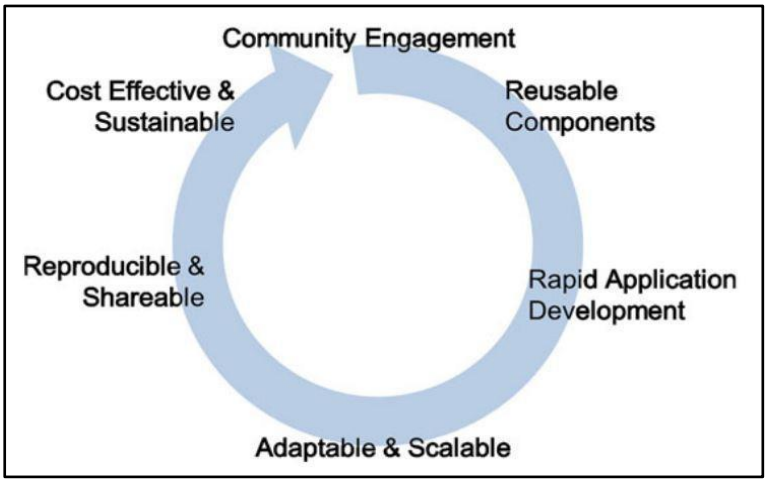
- The research team do not elaborate on their collaborative approach.

Mwangonde, Ntinda, & Hasheela-Mufeti (2021) state that preserving a country's culture is vital for its economic, social, and environmental aspects, from cultural heritage to cultural and creative industries. One effective way of preserving culture is by transferring cultural knowledge to the younger generation (Omeluzor, Imam & Bamidele, 2014). Games are an effective medium for generating interest and educating the youth (Hasibuan, Isal, Ahmad & Selviandro, 2011). In the study by Mwangonde et al. (2021), the authors discuss the development of a mobile game aimed at preserving the culture of the Ovambo tribe of Namibia and educating the Ovambo youth. Participants tested the game, and all features aligned with the requirements identified during the planning phase. An internal team conducted tests for bugs, and participants provided valuable feedback on issues and suggestions for improvements. Before the final release, insights from fourth-year IT students were incorporated to enhance the game's technology (Mwangonde et al., 2021).
Insights, observations or lessons learned:

- The research team do not elaborate on their collaborative approach.

Summers, Salazar, Olszyk, Harwell & Brookes (2020) published a report on the functionality and usefulness of the Decision Integration for Strong Communities (DISC) application. The DISC app would help small towns and rural communities address sustainability goals. The development process utilised the Agile Scrum framework and involved a Scrum team comprising experts in ecological, social, community planning, and computer sciences, as well as two development teams. The entire DISC team came together weekly and primarily used email for communication. The DISC community engagement teams interacted directly with towns in Washington and Oregon and some Northwestern tribes of America. Communication with smaller towns was via community representatives. Engagement with community partners involved both face-to-face and virtual meetings. It was initiated as early as two years before the start of the DISC project and continued through the first year. At the meetings, the teams discussed progress, shared project and communication plans, managed expectations for product deliverables and addressed community engagement fatigue. Figure 6 shows the DISC application life cycle.

Figure 6. *DISC application life cycle approach to iterative Agile development*



Note. From *The Development of DISC (Decision Integration for Strong Communities): An Agile Software Application of Sustainability Indicators for Small and Rural Communities* (p. 92), by Summers et al., 2020.

Insights, observations or lessons learned:

- A relationship between the research team and participants was established two years before the start of and continued throughout the project.
- The authors do not mention the use of Indigenous or cultural practices when engaging or collaborating with community partners.

Bekele, Biru, Sametinger, Groher, Floyd, and Pomberger (2019) developed an Android app to support pregnant women in Ethiopia using ethnography to understand local customs (Maier & Thalmann, 2012). Their project included a development team of programmers and a user study team, following iterative steps: (1) Situational inquiry for requirements, (2) Build process with designs and prototypes, and (3) Evaluation through testing and redesign. During requirements gathering, the research team observed health workers during home visits and interviewed them to understand their daily activities. They built rapport with mothers by using cultural greetings, learning the local language, discussing coffee, engaging with children, and helping with chores, which encouraged open sharing of information. Each interview included one public health member and one technology member, with a focus on gender balance by ensuring at least one female participant. Public health professionals contributed the health information for the mobile prototype app. Twenty users, including 10 mothers and 10 health workers with no prior tech exposure, tested the prototype and provided feedback. The user study team engaged closely with users and programmers,

fostering ongoing, informal consultations to understand requirements, roles, and project plans. This collaboration built a strong relationship with users and, unlike traditional ethnographic studies by a single researcher, the diverse perspectives of the team improved the quality of transferring field study results to design.

Insights, observations or lessons learned:

- The research team made repeat visits to the workplaces and living areas of their study participants to develop meaningful working relationships. This was important for the user community to feel at ease and therefore become active in the deployment and use of the software tools.
- The user study team worked closely with both users and programmers fostering ongoing, informal engagement to understand requirements, etc.

Verbiest et al. (2019) provide an overview of the codesign methods and processes used to create the OL@-OR@ app (Te Morenga et al., 2018). The OL@-OR@ app addresses health risks of non-communicable diseases among Māori and Pasifika communities in Aotearoa New Zealand. These authors describe the partnership between the academic research team and the target communities. Over seven face-to-face meetings, the academic research team and community partners collaborated to build their relationship, establish a team culture, and build capacity. The meetings ranged from 2 to 6 hours, in which they collectively discussed project values and formulated a group agreement. These included trust, respect, empathy, and empowering communities. Since the project followed a codesign approach and involved Māori and Pasifika communities, the initial research team was broadened to include academic Māori and Pasifika researchers. Also, a Māori codesign expert facilitated the codesign workshops and training. The participatory co-design cycle described by Bratteteig, Bødker, Dittrich, Mogensen and Simonsen (2012) was adapted for this project. The cycle involved collaborating with target communities to identify opportunities, understand needs, gather knowledge, envision the mHealth tool, and test prototypes. They also integrated culturally specific health frameworks representing worldviews of the Māori (Te Whare Tapa Whā and Te Pae Mahutonga) and Pasifika (Fonofale) communities to ensure the app design met their needs. Additional Māori themes like whanaungatanga (building relationships), mātauranga (knowledge), whakapapa (genealogy), rangatiratanga (leadership, self-

determination), whakapono (faith), and whakataukī (sayings/proverbs) were acknowledged and integrated throughout the intervention.

Insights, observations or lessons learned:

- The research team required additional academic Māori and Pasifika researchers.
- The codesign workshops and trainings were facilitated by a Māori codesign expert.
- The authors acknowledge the use of Indigenous or cultural practices when engaging or collaborating with community partners.

Hossain et al. (2017) describe their efforts in applying the PRISMA (Participatory action Research In Software Development Methodology Augmentation) model (Siew et al., 2011) in collecting user requirements for the design of a transcription tool. This tool will assist in culture and language preservation for the Kelabit community of Bario, Sarawak. The PRISMA model combines two parts: (1) a software development process that employs the traditional Software Development Life Cycle (SDLC) and (2) a social change process that deals with the changes the community wants, the reasons they want it, the roles of people in political and social systems, and multiple disciplines, environments and stakeholders. The PRISMA model has eight steps: community selection, rapport building, problem exploration, hypothesis formation, design/methodology, implementation/testing, and evaluation/reflection. Kelabit was the community for this project. The Bario radio station provided the audio files for the transcribing. An established relationship between the researchers and the community made discussion and feedback exchanges comfortable. Existing transcription tools may not be suitable for this community. Therefore, participants tested four existing transcription tools, and the feedback and recommendations helped design a prototype of the Kelabit transcription tool.

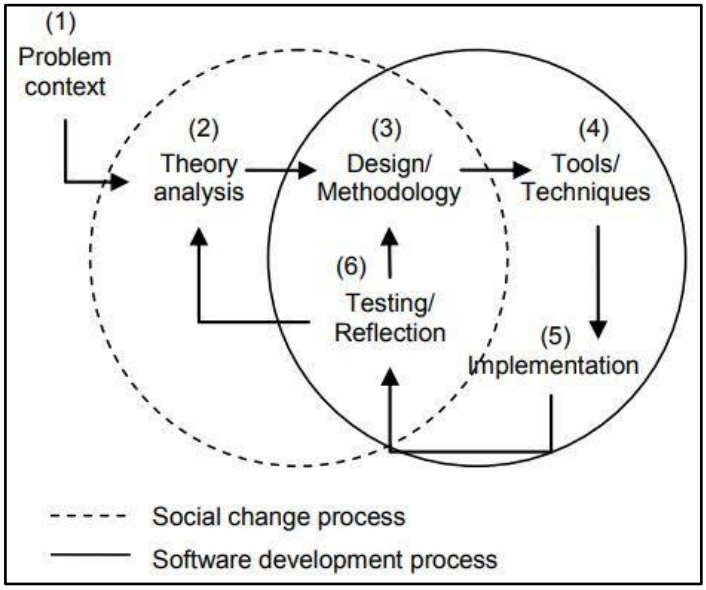
Insights, observations or lessons learned:

- An established relationship between the researchers and the community made discussion and feedback exchanges comfortable.
- There is no mention of Indigenous or cultural practices in this paper.

Siew & Yeo (2011) proposed their **P**articipatory action **R**esearch **I**n **S**oftware development **M**ethodology **A**ugmentation or PRISMA model. The model is a

composition of “participation” and “action research” in Software Engineering. These authors argue that software development for rural communities needs to be participatory and must follow a community-driven approach for analysis, planning, monitoring, and evaluation. After several case studies, these authors conclude that PRISMA is appropriate for developing software for rural communities. The Social Change process (dashed circle), as shown in Figure 7, specifies the collaboration efforts of the research and development team working with the target community, and other stakeholders (Siew & Yeo, 2011). There are three steps involved in the social change process that brings the target communities (users), developers, and researchers together. To co-define research goals and ensure equal power in decision-making, the communities must collaborate with researchers. This partnership promotes informed local decisions and generates valid knowledge that aligns local expertise with societal needs.

Figure 7. *PRISMA model*



Note. From *Employing Participatory Action Research to Augment Software Development for Rural Communities* (p. 174), by Siew & Yeo, 2011.

Siew & Yeo (2012) report the use of PRISMA to design a mobile-based healthcare application for a remote Penan community in Borneo, Malaysia. Successfully applied in projects with rural communities, PRISMA strengthens community participation and ensures software applications are built in the community’s best interests. The healthcare app targets young children and mothers and promotes good hand-hygiene practices.

Siew, Yeo & Zaman (2013) report the use of PRISMA to develop eToro, an Indigenous Knowledge Management System (IKMS) for the Penans, a remote and rural Long Lamai community in Malaysian Borneo. The Long Lamai community has maintained a positive relationship with Universiti Malaysia Sarawak (UNIMAS) since 2007, starting with a telecentre project that fostered good rapport and mutual respect. The eToro project aims to safeguard the community's traditional knowledge, which is at risk of vanishing due to the gradual decline of the elderly and a lack of interest among younger generations. PRISMA was described to augment the conventional SDLC and employed to develop software for rural communities.

Insights, observations or lessons learned regarding the PRISMA model (Siew et al., 2011, 2012, 2013):

- The authors augment an existing software development life cycle with participatory action research to create a framework suitable for involving rural communities in software development process.
- The authors argue that software development for rural communities needs to be participatory and must follow a community-driven approach for analysis, planning, monitoring, and evaluation.
- To co-define research goals and ensure equal power in decision-making, the communities must collaborate with researchers.

Simba et al. (2009) introduce a software system, Connectivity Cost Calculator, designed to calculate the cost of connectivity to rural areas of Tanzania. The app aims to provide easy access to connectivity cost information from different technologies and operators. The development of the calculator follows the V-model software development lifecycle and is used to assess the economic viability of potential technologies for providing rural connectivity.

Insights, observations or lessons learned:

- The authors do not elaborate on their collaborative efforts.

Alazzam et al. (2021) detail the development process for their Patient-Doctor-Specialist mobile app. The app aims to connect patients with healthcare professionals, allowing prompt access to specialist medical treatment through internet connectivity. Consequently, patients in rural areas can avoid unnecessary trips and reduce wait times in critical situations, ultimately saving time and money.

The app's development involved the Design Thinking process, the Running Lean process, the Evolutionary development model and selected activities from the Agile Scrum framework. The Design Thinking process outlined four steps: (1) Empathy, which involved interviews with villagers and medical specialists. Visits to rural areas were necessary to connect with villagers and build relationships, ultimately saving the villagers travel costs; (2) Define and devise: which involved synthesising responses from step one to define a possible solution; (3) Prototype and Validation: involved proposing and validating a prototype, and (4) Documentation: which involved documenting the business model. The Running Lean process facilitated the engagement with participants in two stages. Each stage involved selecting SCRUM activities and defining the capabilities of the mobile app through four-week sprints, engaging with users, gathering feedback, and documentation.

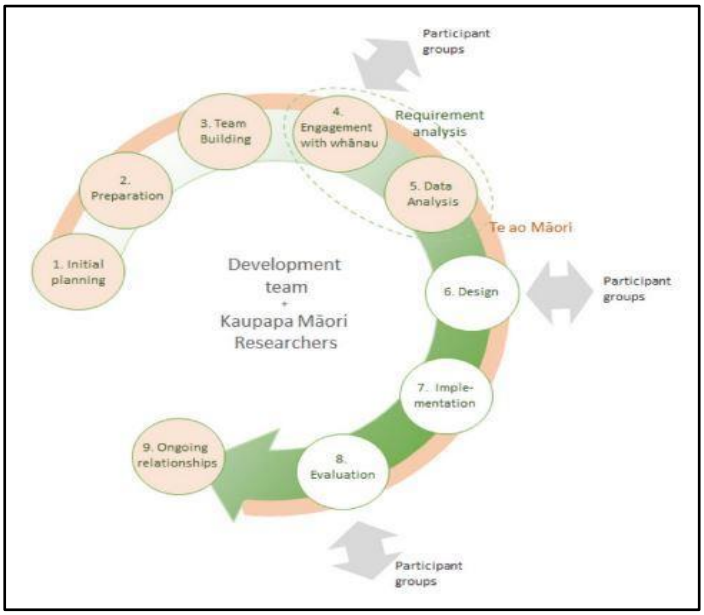
Insights, observations or lessons learned:

- The research team made visits to rural areas to connect with villagers and build relationships, ultimately saving the villagers travel costs.

Rolleston et al. (2021) discuss the collaboration between Māori and Tauiwi (non-Māori) researchers on a software engineering project. They highlight critical partnership factors for successful collaboration often overlooked in project reporting. In Aotearoa New Zealand, a Māori foundation is essential, with a significant emphasis on understanding Te Tiriti o Waitangi (The Treaty of Waitangi). This 1840 agreement between the British Crown and over 500 Māori chiefs established the basis for Māori-led research involving Māori participants and impacting Māori outcomes. The project team comprised two Tauiwi computer scientists, one Welsh, one German, and three researchers of Kaupapa Māori (Māori principles and values). A typical participatory design process would not adequately address the post-colonial context of Aotearoa and Te Tiriti. To better support Māori workers, Māori leadership was essential for adopting an approach of Kaupapa Māori (Māori principles and values) and expanding the design process to include Te ao Māori (the Māori worldview). Throughout the research, a korowai (cloak) framed the project to prioritise Māori values, beliefs, and culture. Key concepts included tuakana (older sibling) and teina (younger sibling), highlighting reciprocal relationships in teaching and learning, manaakitanga (kindness and care), Tikanga (Māori cultural methods), and ngāwari (flexibility). Ultimately, this collaboration expanded the traditional 4-step software design process to a nine-step

integrated process grounded in Te ao Māori (the Māori world view) and Kaupapa Māori (Māori principles and values), as shown in Figure 8.

Figure 8. *Enhanced Participatory Design with Kaupapa Māori and Te ao Māori*



Note. From *Collaboration in research: weaving Kaupapa Māori and computer science* (p. 472), by Rolleston et al., 2018.

The extent of user participation is influenced by the design methodology. In codesign, users are engaged as equal and active collaborators throughout the process. In participatory design, users may provide input at each stage but may not be directly engaged in implementation. Participatory design presents several benefits such that end-users work with the development team at key stages of the design process, as shown in Figure 8.

Guiding principles of Kaupapa Māori:

1. Tino rangatiratanga – sovereignty, autonomy and self-determination, where control and determination of the research sit within Māori cultural understandings, values and practices;
2. Manatika pāpori - social justice, where Māori benefit from the research, and there is the opportunity to build Māori research capabilities;
3. Te ao Māori - the recognition and privileging of the Māori world
4. Whakawhanaungatanga - the process of creating and maintaining relationships that allow for an in-depth conversation to occur between the researcher and the participants;

5. Te Reo Māori - the Māori language, using Te Reo Māori whenever possible, and although the reality is that many Māori researchers and participants may not be fluent in Te Reo Māori, the opportunity is given to gain more understanding of the research
6. Whānau - refers to family and extended family. Whānau affirms the idea of the collective in understanding and sharing research findings (Walker, Eketone & Gibbs, 2006).

(Rolleston et al., 2021, p. 471)

Insights, observations or lessons learned:

- In Aotearoa New Zealand, a Māori foundation is essential, with a significant emphasis on understanding Te Tiriti o Waitangi (The Treaty of Waitangi).
- To better support Māori workers, Māori leadership was essential for adopting an approach of Kaupapa Māori (Māori principles and values) and expanding the design process to include Te ao Māori (the Māori worldview).
- The extent of user participation is influenced by the design methodology.
- In codesign, users are engaged as equal and active collaborators throughout the process.
- Participatory design presents several benefits such that end-users work with the development team at key stages of the design process

LaPensée (2020) presents her SPEAR (Sovereignty, Positionality, Equity, Advocacy, and Reciprocity) framework that supports the design and development of Indigenous cultural games, emphasising the participation of Indigenous people as collaborators throughout the development process. This author uses the SPEAR framework to create her Thunderbird Strike game. During the game's development process, LaPensée closely collaborated with the programmer and Indigenous game developers. LaPensée suggests SPEAR as a guide for conveying Indigenous cultures through game design and developing Indigenous cultural games, mainly where collaboration with Indigenous contributors is concerned with Indigenous research.

Insights, observations or lessons learned:

- The author closely collaborated with the programmer and Indigenous game developers.

Longboat (2019) analysed what makes a video game Indigenous. He examined the works of authors who actively create media as part of their research, as well as Indigenous scholars who employ decolonial and Indigenous research methodologies (Smith, 2012; Bennett, 2012; LaPensée, 2016). Longboat concluded that an Indigenous video game is shaped and led by Indigenous peoples. This leadership should extend across various aspects including creative direction, game design, programming, distribution, and more (Longboat, 2019). Without the participation of Indigenous individuals in decision-making roles, there is a risk of perpetuating harm to Indigenous peoples and their cultures.

As an outcome of his study, Longboat (2019) developed an Indigenous video game, Terra Nova. The Indigenous Sci-fi video game is set in a post-apocalyptic future and focuses on a 'first contact' survival scenario. In the game, the player experiences 'Indigenous' meets 'Settler' for the first time, whether playing the former or the latter character. Colonialism has affected many Indigenous communities since the 16th century, and moments of first contact between Indigenous and Settler peoples have occurred countless times. These encounters are remembered today through oral and recorded histories (Longboat, 2019). Through this game, the author expresses "survivance" on his terms, reflecting his identity and intentionally embedding these qualities within the game's story and mechanics. *Survivance* acknowledges that despite colonial oppression, Indigenous peoples not only survive but thrive (Vizenor, 2008).

In the context of this research, I consider the development process Longboat (2019) used to create Terra Nova, his Indigenous video game. The practise-based approach, Research-Creation, involves analysing the media while developing it and combining scholarly writing about it (Chapman & Sawchuk, 2012). Furthermore, this approach explores methodological frameworks of how Indigenous video games are created which allows the researcher to incorporate their experience and reflections (Longboat, 2019).

The design and production process of the game Terra Nova involved two phases. The Pre-production phase involved the planning activities before the implementation and prototyping in the Production phase. These phases and subsequent phases are mapped in Table 12 of Section 3.3. Also, during the development of Terra Nova, as a

first-time Indigenous video game developer, Longboat (2019) consulted the Skins curriculum model as a guide. The Skins Aboriginal Storytelling and Video Game Workshops for Indigenous youth were created by the Aboriginal Territories in Cyberspace (AbTeC). The workshops encourage teens to use computer technology for creative expression and production. Participants also use their cultural knowledge in game development and draw on this knowledge to inform the game's development cycle (Longboat, 2019).

Longboat (2019) urges the video game industry to engage in more equitable and ongoing consultation with Indigenous individuals and communities. He emphasises that consultation played a significant role in the Terra Nova video game. Longboat (2019) also points out that video game development is rarely done by one person, and the success of his project would not have been possible without the collaborative efforts of his teammates, mentors, and fellow developers. Furthermore, Longboat (2019) acknowledges the works of many important developers, artists, thinkers, writers, and scholars who have contributed to the breadth of what Indigenous video games can be. The Terra Nova project is his contribution that challenges the current methods of how development communities within the industry choose to include or silence the Indigenous voices affected by the creation of their games (Longboat, 2019).

Insights, observations or lessons learned:

- Storytelling is an integral method of building an Indigenous presence in the digital territory
- Indigenous video games are made by Indigenous peoples.
- Games made by Indigenous peoples communicate their unique narratives through the medium.
- Indigenous video games express specific Indigenous communities and cultural contexts.
- Indigenous video game development must be Indigenous led.
- Consultation with Indigenous individuals and communities is important and must be considered.
- Indigenous video game development requires collaborative and team effort.

Singh, Bisht and Sundriyal (2018) developed an online decision system support tool called the Village Information System (VIS). VIS is a two-way information system. The information flows from the villagers to government departments and back again. This system helps government officials and policymakers access updated information about villages.

The development team used the Software Development Life Cycle (SDLC) to develop the online Village Information System (VIS), with active involvement from the Indigenous users, NGOs, government departments, etc., throughout the process. The stakeholders identified and finalised key issues through group discussions, meetings, workshops, and brainstorming with the system stakeholders. The datasets were collected, analysed and compiled.
Insights, observations and lesson learned:

- The development team actively collaborated with the relevant stakeholders; however, they did not elaborate further on their collaborative efforts.

Te Morenga et al. (2018) developed the OL@-OR@ app, a culturally tailored, mHealth app supporting healthy lifestyles and weight management for Māori and Pacific communities in Aotearoa New Zealand. These authors describe their integrated process of the Participatory Co-design and Kaupapa Māori Research (KMR) approaches used to create the app. These authors argue that this process should be considered best practice for developing apps involving Māori communities.

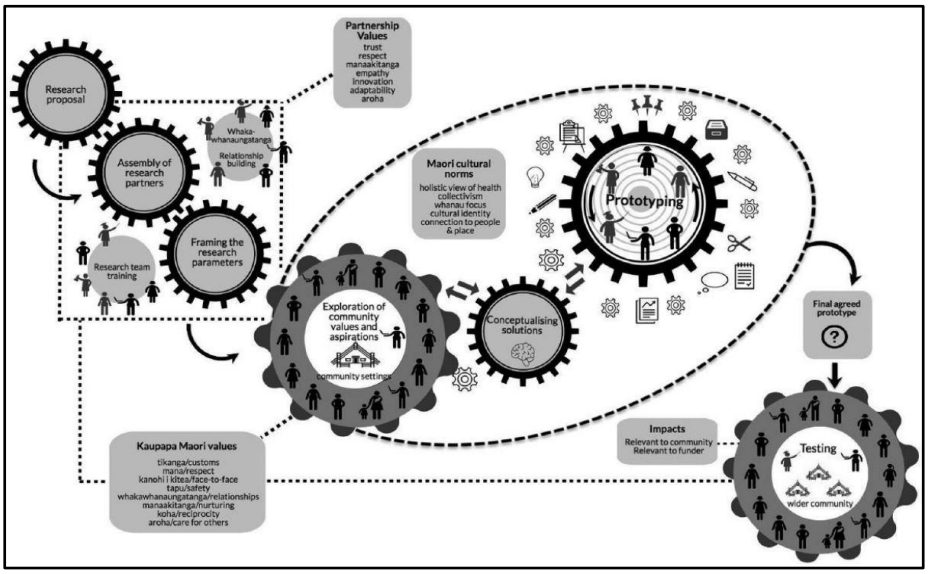
This project enabled the Māori partners to lead the conceptualisation, design, implementation and interpretation of research outcomes. Two Māori researchers affiliated with the communities were involved in the project. One led the engagement, and both facilitated the consultation. Having these researchers was essential for establishing trusting relationships. However, as Māori work toward self-determination and against historical injustices (Smith, 2012), building relationships and trust with Māori communities takes time. Therefore, the community researchers found it hard to balance the needs and timeframes of academic researchers with the availability and readiness of the communities contributing to the research process.

The research team established rapport and understanding by introducing a “principles of engagement” framework based on Whakawhanaungatanga (process of creating and maintaining relationships). The team participated in face-to-face meetings to

develop a team culture and set principles for working together to meet project objectives. They exercised cross-cultural communication, had training in design thinking approaches, and learned from a Māori codesign expert how to apply those approaches with Māori communities. Additionally, they learned about mHealth technologies. After the research team set a collective understanding, they organised and facilitated hui (meetings) with target end-users. The community researchers facilitated two focus groups with Māori participants and followed Kaupapa Māori (Māori principles and values). Each hui (meeting) included karakia (blessing), introductions, and kai (food).

Te Morenga et al. (2018) say that the Co-design approach is compatible with Kaupapa Māori Research (KMR) and is intrinsically mana-enhancing. Thereby Māori whānau (family and extended family) and communities are culturally empowered to generate discussion and insights through their knowledge systems, stories, proverbs, and oral histories. Consequently, these authors adapted the Participatory Co-design cycle (Bratteteig et al., 2012) by integrating Kaupapa Māori Research (KMR) principles and Tikanga Māori (Smith, 2012; Walker et al., 2006). These authors state this integrated approach empowered their target communities to participate in the research process. Figure 9 shows the process for designing the OL@-OR@ app:

Figure 9. *Kaupapa Māori Co-design Process*



Note. From *Co-designing an mHealth tool in the New Zealand Māori community with a "Kaupapa Māori" approach* (p. 3), by Te Morenga et al., 2018.

Insights, observations or lessons learned:

- Research projects involving Māori and impacting Māori outcomes, must invite Māori to lead the engagement and consultation.
- Research projects involving Māori and other communities requires time and resources.
- By adapting a known software process (e.g. Participatory Co-design) with a research approach that incorporates the principles and norms (e.g. Kaupapa Māori Research) of the communities involved is essential for understanding and meeting the needs and desires of those communities.
- A research team can learn to work with Māori and other ethnic groups by educating themselves in the principles and values that are important to the target community/ies.
- The research team established a set of tikanga principles to manage their team conduct and resolve issues that arose.

Dobson et al. (2017) describe the process of developing TextMATCH: Text for MATernal and Child Health. TextMATCH is a culturally tailored text message-based maternal health program. It contributes to disease risk management of pregnancy, mother and child nutrition and physical activity to influence lifelong health for families living in Aotearoa New Zealand. The mHealth Development and Evaluation Framework introduced in a study by Whittaker et al. (2012), helped guide the development of TextMATCH. Dobson et al. (2017) adapted Whittaker et al.'s version, here are the steps:

1. Conceptualisation & consultation
2. End-users focus groups
3. Review of guidelines, research evidence, and resources
4. Develop key messages
5. Adaptation of key messages for SMS
6. Expert review (Round 1)
7. Expert review (Round 2)
8. Cultural adaptation
9. Cultural review
10. Translations
11. Review
12. Testing
13. Implementation

Focus groups were conducted with the target audience to determine how they engage with technology, how the program could benefit them, and to understand cultural norms, traditions, and beliefs around technology and maternal health. The target audience consisted of pregnant women and mothers of babies from ethnic communities Māori, Pacific, Asian, and South Asian from two health districts in Auckland, New Zealand. A consortium of community-based providers, Roopu Kaitiaki worked with the target audience, by providing focus and scope of the program. Dobson et al. (2017) observed that guidance and references specific to New Zealand were preferred, as advice about international apps may not align with New Zealand practices. Also, these authors identified differences in terminology, culture-specific foods, practices, traditions, and activities among the focus groups. Consequently, the differences support the need for culturally adapted program versions. Moreover, the target audience wanted the intervention to be in a language they were likely to communicate with their lead carer. Therefore, each version included the English language. Other ethnic versions included Te Reo Māori, Japanese, Chinese and Korean. Dobson et al. (2017) point out that it is not simply about translating programs for the majority but considering the minority populations first, and that we must dedicate time and resources to ensure these programs are relevant to the target audience and well-suited to their daily lives.

Insights, observations or lessons learned:

- We must dedicate time and resources to ensure programs are relevant and well-suited to the target audience.

Teka et al. (2017) explain their adaptation of User-Centered Design (UCD) methods with agile development practices to improve software projects. The authors conducted a study involving two projects at an Ethiopian software company. They combined action research with surveys and interviews from other companies. Deliberation meetings and workshops helped implement the proposed solutions in collaboration with practitioners. Personas and local IT staff were vital in facilitating communication between developers and users. Personas helped understand needs, design, and test locally. They also allowed the offshore team to understand users' needs better. Effective personas can connect software developers and users, especially in low- and medium-income countries. Because of the diversity and distance in these areas, it is

essential to create personas carefully and early. User stories and backlogs help shape the requirements.

Insights, observations or lessons learned:

- Deliberation meetings and workshops helped implement the proposed solutions in collaboration with practitioners.

Isabirye, Flowerday, Nanavati, and Von Solms (2015) developed a voice-based e-Marketplace deployed in a rural South African aloe farming community. The Aloe e-Marketplace was created using the Spoken Web platform and given to participants to provide feedback. These authors present a model used to develop applications based on action research. The users rigorously tested the Aloe e-Marketplace. The authors conducted desktop research and telephone interviews, followed by an iterative Joint Application Design (JAD) process among the collaborating researchers to enhance their understanding of the activities involved. Also, the researchers visited two aloe communities to refine the modelled requirements and encourage participation from the identified communities.

Insights, observations or lessons learned:

- The researchers visited the two aloe communities to refine the modelled requirements and encourage participation.

Huang & Huang (2013) developed a framework for their video game, Papakwaqa, to enhance school children's learning, motivation, and performance related to the life and history of Taiwan's Indigenous people. The developers transformed cultural components into elements integrated into the game's user interface. The cultural characteristics and historical education goals were analysed and used to validate the game's framework and storytelling engine. The game designers collaborated with the historians, educators and anthropologists to integrate cultural elements and align them with the game design methodology.

Insights, observations or lessons learned:

- The authors say the game designers collaborated with the relevant stakeholders but did not elaborate on the collaborative efforts.

Whittaker et al. (2012) established a process for developing and testing mobile phone-based health interventions called the Development and Evaluation Framework. These authors implement the process on several mHealth interventions developed in

Aotearoa New Zealand. The following steps form the process: conceptualisation, formative research to inform the development, pretesting content, pilot study, pragmatic randomised controlled trial, and further qualitative research to inform improvement or implementation. The strengths of the process include engaging the target audience during its development and utilising rigorous research methods. Additionally, the target population participated throughout the process.

Insights, observations or lessons learned:

- The authors do not elaborate on their collaboration efforts.

Chetty (2005) discusses a socially aware computing framework and MuTi, a prototype for remote health consultations in rural areas. By integrating user-centred methodologies and lessons from previous ICT initiatives, the authors enhanced the standard software development life cycle. The project involving university researchers and local community members took place in the rural village of Tsilitwa, South Africa. A lecturer led discussions and managed administrative tasks, while a master's student fostered relationships, assisted with software installation, and provided training. The author handled software development, prepared materials, documented the project, and conducted training sessions. Community members participated in discussions and workshops throughout the project. Engaging with the target community necessitates a trusted individual, an "ally" or "local champion", who can interpret between researchers and community members. This champion shares a similar background, speaks the same language, and is a respected authority, exemplifying technology use. Chetty notes that researchers can also serve as allies if they meet the criteria.

Insights, observations or lessons learned:

- The author recommends that community engagement requires a trusted individual, a local champion, to interpret between the researchers and community members.
- The author also recommends that a researcher serve as an ally if they come from similar backgrounds as the target community, speak the same language, is a respected authority, and a competent technology user.

Zaman et al. (2015) aimed to reintroduce the Penan youth to their cultural heritage via Oroo'. Oroo' is a digital game named after the Penan traditional forest sign language,

of which most youths have limited awareness. The authors describe their collaboration with the Penan Long Lamai community of Borneo Malaysia, focussing on requirements gathering. In 2007, Universiti Malaysia Sarawak partnered with the Penan community. The collaboration continued with a project to digitise Oroo' in 2012. At that time, the Penan elders were concerned about losing their cultural heritage as the children were more interested in digital games than going into the forest. The elders explored the potential of technology and digital games to bridge the intergenerational knowledge transfer gap and, as a result, helped to create the Oroo' game. The community organised several forest visits to demonstrate the Oroo signs. These visits were recorded and photographed, with an Oroo' expert present at each session. Local artists were also involved to recognise the Oroo' signs in the photographs. Three focus group sessions took place: one with elders (aged 50 and older) to catalogue Oroo' signs, and two with 20 people (aged 18-41) to assess their knowledge of the signs. The group, aged 30-41, knew the signs, some up to ten. Additionally, a test revealed that only 1 out of 17 children (aged 8-16) knew two signs, and the rest knew none. Therefore, the research team focused on the children most at risk of losing their language and culture.

Insights, observations or lessons learned:

- The authors briefly describe their 5-year relationship with the Penan community, highlighting the 2009 telecentre initiative before this 2012 project.
- The authors briefly describe their work with the Penan community but do not give insights into the community, culture, or people.
- The authors conducted focus groups with the Penan community. However, there was no mention of cultural traditions during these sessions.
- The authors would visit with the elders. Meeting face-to-face with the Indigenous community is an essential feature of development projects.
- The authors recorded and photographed each forest session with an Oroo' expert.
- The authors do not explicitly list insights for working with Indigenous communities.

Yasir et al. (2014) introduced Beetles, a mobile phone-based solution to help farmers detect crop disease. The authors outlined two phases in their system design: the user interface and the system development process. While they detailed the algorithms

used in their detection program, they briefly presented the users' experiences with the app and their evaluations. Some users provided negative feedback; one farmer questioned the app's effectiveness, while others expressed concerns about its cost on their phones. However, the creators recognised a need and developed a solution, but failing to involve their target audience in the development process led to many suggestions for improvement.

Insights, observations or lessons learned:

- Users were involved in the evaluation of the Beetles app.
- It is crucial for the success of software developed for Indigenous communities to involve them from the outset.
- The authors do not explicitly list insights about working with indigenous communities.

Leavy et al. (2007b) report on their Torque Game Engine (TGE), a digital platform for Indigenous Australian storytelling. The report outlines the project cycle, improvements to the TGE, and key features of the Digital Songlines Engine (DSE). The Digital Songlines (DSL) game engine (DSE) is built on and extends the TGE. The report concludes with an overview of these four implementations of the DSE: (1) Virtual Warrane, (2) Vincent Serico's world, (3) Irene Ryder's world, and (4) Virtual Australia.

Each project or implementation followed an iterative cycle, with initial planning done in consultation with the community and continued throughout the development. An authentication process finalises the project. During site visits, with permission, team members may collect photographs, videos, sounds, samples of local materials and landscape features, and more. Clients provide information about what they want to see in their simulated country, the stories, what animals are needed and so on. The collection of agreed fauna and flora is modelled, animated and embedded in its 'country' of origin.

These authors say that a set of protocols with Indigenous people was adopted at each stage. They point out that the protocols are outlined in one of their other papers (Leavy et al., 2007a), and I list these below. In the other paper, the authors say that it is important to establish protocols for handling intellectual property and copyright issues related to Aboriginal cultural knowledge. This is to ensure that such knowledge is respected, recognised, and protected from misuse.

Protocols for involving Indigenous people:

1. That the stories of Traditional Owners be recognised as a 'body of knowledge' that may be tens of thousands of years old.
2. That the stories are sourced from the Traditional Owner who represents the country from which that story might originate.
3. That the communities make their own decision on what stories they want to have represented in any Virtual Heritage project.
4. That an approval process be implemented and approved by communities.
5. That the story represents the community and clan, and is specifically placed geographically.
6. That ownership and copyright of the story is always held by the nominated traditional owner group or community council.
7. That the content of the Virtual Heritage application including artist styles is approved by the community at all key production stages.
8. That the story provided by the community is not modified unless approved and endorsed by the Traditional Owner representative of that community.
9. That the community be paid industry standard rates and receive royalties from revenue earned from any capitalisation and commercialisation.
10. That indigenous people design and participate in the creation of the Virtual Heritage application development at all stages of planning, design and production.

(Leavy et al., 2007a, p. 165)

These authors elucidate that the need to provide accurate and affordable Indigenous Australian cultural knowledge will benefit Indigenous and non-Indigenous people in Australia, as well as global cultural heritage.

Insights, observations or lessons learned:

- Consultation with the community was implemented throughout the project cycle.
- The authors say it is important to establish protocols for handling intellectual property and copyright issues related to Aboriginal cultural knowledge.

Mann et al. (2006) discuss their SimPā project and 3D game, which aim to promote and preserve the cultural practices of the Māori Kai Tahu (Ngai Tahu in the Northern Māori dialect). The project acknowledges participation from Indigenous stakeholders

and facilitates participatory game design. The Rūnaka members (Rūnanga; Māori tribal council) join in to create the 3D game, GamePā, a virtual environment that represents a specific place. The project includes Marae-based workshops called wānaka (wānanga), where participants immerse themselves in Māori tikaka (tikanga) traditions, environment, and history under the guidance of local Rūnaka elders. The SimPā project provides a unique approach to using ICT to benefit Indigenous people. The following points make up these authors' unique approach:

1. on marae, providing experience of ICT in a familiar environment during wānaka sessions
2. ICT provided according to tikaka Māori
3. skilled ICT people available
4. value knowledge of older generation and skill of younger generations. Encourage combination and mutual contribution. Side-by-side participation.
5. potential benefits for participants encourages them to use ICT
6. content and resource material is from the community, in this project ICT is a vehicle
7. procedures in place to ensure protection of knowledge ownership (can be a significant barrier to use of ICT, particularly for Māori)

(Mann et al., 2006, p. 168)

Insights, observations or lessons learned:

- The researchers conduct workshops in a familiar environment for the Indigenous group, such as marae (Māori meeting ground).
- The researchers acquire guidance and leadership from Indigenous elders and locals of an area.

Fleer (1989) described the educational software Tjina, which was co-designed with Aboriginal students. The software provides opportunities for students to read and interact with stories based on Australian content using a book and cards as they progress through the software. When developing the software, the author consulted with a committee of both Aboriginal and non-Aboriginal educational practitioners. Although Fleer does not indicate a co-developed process when creating Tjina, she does say the package was tested by Aboriginal people and its use was trialled in several schools around Western Australia. The students experience trialling the

software was positive and that non-Aboriginal students commented the software gave them a greater understanding of Aboriginal culture.

Fleer (1989) provided a list of design principles she considered when designing Tjina:

1. familiar content (e.g. Australian animals)
2. inclusion of Aboriginal characters in the graphics and text
3. familiar life experiences (e.g. hunting, family)
4. inclusion of cultural values and beliefs where appropriate (e.g. importance of the extended family, less emphasis on the assumption of a nuclear family)
5. the need for community involvement in the software design process, resulting in traditional norms being maintained (elders passing on the knowledge), cultural sensitivity, and appropriate content and emphasis
6. emphasis on graphics and animation, to support Aboriginal cognitive strengths
7. greater interaction by students, particularly peer and group work;
8. self-selecting difficulty levels
9. open-ended design; and
10. easily modifiable text to cater for a range of literacy skills and school environments

(Fleer, 1989; p30)

Insights, observations or lessons learned:

- The researcher established design principles that were considered in the creation of the Tjina software.
- The researcher consulted with a committee of both Aboriginal and non-Aboriginal educational practitioners.

Categorising the 27 software development projects

After analysing the 27 papers, I list the software projects and Indigenous groups involved, as shown in Table 9. Eighteen of the 27 papers describe a software process for associated software app. Four papers describe a software process, and five describe a software app. Although I focus on software development processes, I include the papers detailing a software app to better understand collaboration efforts, when research and development teams work with Indigenous people. I discussed the five software applications in the previous section.

Table 9. *27 software development projects involving Indigenous people*

UID	Software process	Software application	Target Indigenous group
18 software applications with a prescribed software process			
HUM2022	Cocreation Methodology	Manaaki: Gambling prevention mobile app	Māori and Pacific Island people, Aotearoa NZ
ALA2021	Design Thinking + Running Lean + Evolutionary + Agile SCRUM	Patient-Doctor-Specialist mobile app	Rural community, Iraq
MWA2021	GDLC[13]	Ovambo Master: Cultural preservation game	Ovambo tribe/youths, Africa
LAP2020	SPEAR[14] + Agile	Thunderbird Strike: Indigenous game	Anishinaabe and Métis, Canada
SUM2020	Agile SCRUM	DISC web app	Rural community, Northwestern Indian tribes, Washington and Oregon, USA
BEK2019	Ethnography research & design process	Android prototype app	Health workers and pregnant women, Ethiopia
LON2019	Research-creation Production Cycle	Terra Nova	No specific target, First Nations influence
VER2019	Participatory Co-design Cycle	OL@-OR@ app	Māori and Pacific Island people, Aotearoa NZ
SIN2018	System Requirements Specification + SDLC[15]	Village Information System web app	Rural communities, India
TEM2018	Co-design + Kaupapa Māori	OL@-OR@ app	Māori and Pacific Island people, Aotearoa NZ
DOB2017	Development and Evaluation Framework	TextMATCH: Text for MATernal and Child Health	Māori, Pacific, Asian people, Aotearoa NZ
HOS2017	PRISMA	Transcription tool	Kelabit community, Sarawak, Malaysia

[13] GDLC - Game Development Life Cycle
[14] SPEAR - Sovereignty, Positionality, Equity, Advocacy, and Reciprocity
[15] SDLC - Software Development Life Cycle

ISA2015	Canonical Action Research (CAR) + Requirements Elicitation	Aloe e-Marketplace web-mobile system	Farming community, South Africa
HUA2013	Cultural Heritage Framework + Game Design	Papakwaqa serious game	School children, Taiwan,
SIEW2013	PRISMA	eToro Indigenous Knowledge Management System	Penan community, Borneo, Malaysia
SIE2012	PRISMA	Hygiene app	Penan community, Borneo, Malaysia
SIM2009	V-Model	Connectivity Cost calculator web app	Rural community, Tanzania, Africa
CHE2005	Socially Aware Approach: Action Research + Participatory Design	MuTI: Multimodal Telemedicine Intercommunicator	Rural community, East Cape, South Africa
Four software processes with no described application			
ROL2021	Software Design + Participatory Co-design	*no description*	Māori forestry workers, Aotearoa NZ
TEK2017	UCD + Agile + Cooperative Method Development	*no description*	Rural community, Ethiopia
WHI2012	Development and Evaluation Framework	*no description*	Māori people, Aotearoa NZ
SIE2011	PRISMA[16]	*no description*	Penan community, Borneo, Malaysia
Five software applications with no described process			
ZAM2015	*no description*	Oroo' adventure game	Penan community, Borneo, Malaysia
YAS2014	*no description*	Beetles app	Farming community, Bangladesh
LEA2007	*no description*	Digital Songlines Game Engine	Indigenous Australians
MAN2006	*no description*	GamePa	Kai Tahu Māori, South Island, Aotearoa NZ
FLE1989	*no description*	Tjina educational software package	Aboriginal students, Western Australia

[16]PRISMA - Participatory action Research In Software development Methodology Augmentation

In Table 9, 22 (*n*=18+4) software processes are listed. Some of these processes are well-known in software engineering, while others are not generally known. Here, I will categorise the well-known processes as “existing” (an established and widely used software approach) and the others as “integrated” (a combination of existing processes and/or an extension of an existing process), as defined in Chapter 1, Section 1.2. After categorising the 22 processes, I have identified 18 unique ones, as shown in Table 10.

Table 10. *18 processes categorised as Existing (n=7) or Integrated (n=11)*

	Categorised software processes	**UID**
EXISTING	Cocreation Methodology	HUM2022
	Game Development Life Cycle (GDLC)	MWA2021
	Agile SCRUM	SUM2020
	Participatory Co-design Cycle	VER2018
	Research and Design process	BEK2019
	PRISMA	HOS2017, SIE2013, SIE2012, SIE2011
	V-Model	SIM2009
INTEGRATED	Design Thinking + Running Lean + Evolutionary + Agile SCRUM	ALA2021
	Software Design + Participatory Co-design + Te ao Māori/Kaupapa Māori	ROL2021
	SPEAR (Sovereignty, Positionality, Equity, Advocacy, and Reciprocity) + Agile	LAP2020
	Research-creation Production Cycle	LON2019
	System Requirements Specification + SDLC	SIN2018
	Co-design + Kaupapa Māori	TEM2018
	mHealth Development and Evaluation Framework	DOB2017, WHI2012
	User-centred design + Agile + Cooperative Method Development	TEK2017
	Canonical Action Research (CAR) + Requirements Elicitation	ISA2015
	Cultural Heritage Serious Game Creation Framework + Game Design	HUA2013
	Socially Aware Approach: Action Research + Participatory Design	CHE2005

Table 10 gives an overview of 7 existing processes and 11 processes that integrate existing processes and/or are an extension of an existing process. For example, TEM2018 and ROL2021 combine Kaupapa Māori (Māori principles and values) and Participatory Co-design. These 11 integrated processes will be discussed in detail below.

Mapping Indigenous users in software development processes

After analysing the integrated processes, I will map them using the 6-phase colour model shown in Table 11, which is detailed in Section 3.1. Each colour corresponds to a phase A to F.

Table 11. *A snapshot of the 6-phase colour model*

Phase	**A**	**B**	**C**	**D**	**E**	**F**
Name	**Plan** *orange*	**Design** yellow	**Develop** green	**Evaluate** blue	**Release** purple	**Maintain** magenta

In Table 12, I present the colour mapping of the eleven integrated processes.

The first mapping presents a combination of several existing models, Design Thinking, Evolutionary, Running Lean and Agile SCRUM (UID ALA2021) where the model activities are denoted in two stages: (1) Define a business model and (2) Develop a mobile app. The orange hue represents the Plan phase, while the green hue represents the Develop phase. Each sub-phase is colour-mapped, indicating four phases of the 6-phase colour model: plan (orange), design (yellow), develop (green), and evaluate (blue). From this understanding, we can tell that one stage should be completed before the other begins. However, from the analysis of the ALA2021 integrated process we know that the activities are iterative. Therefore, the sub-phases within each stage may be repeated throughout the cycle.

The four process models with UIDs: ROL2021, LAP2020, TEM2018, and TEK2017, present a unique phase depicted by the light red hue. ROL2021 and TEM2018 include a Māori cultural aspect, such as a Korowai (cloak) that wraps Te ao Māori (the Māori worldview) and Kaupapa Māori (Māori principles and values) around their development process. Whereas the SPEAR framework by LAP2020, presents a First Nation influence that embodies Sovereignty, Positionality, Equity, Advocacy, and Reciprocity over an Agile cycle in its development process. TEK2017 presents a

SCRUM phase that dictates project management and includes the participation of stakeholders throughout their process. The envelopment of cultural aspects, framework values, and stakeholder participation sets these methods apart from traditional or existing development processes. While the integration of one, two, or more processes is a distinguishing factor, these models explicitly indicate user involvement and incorporate cultural principles and values, all the while acknowledging the participation of Indigenous people.

Table 12. *Mapping steps of the Integrated Software Development processes (n=11)*

Process | Step	1	2	3	4	5	6	7	8	9	10	11	12	13
Design Thinking + Evolutionary + Running Lean + Agile SCRUM (ALA2021)	Stage 1: Define business model-Running lean/SCRUM				Stage 2: Develop mobile app-Design Thinking								
	Define capabilities of mobile app	Establish 4-week sprints. Connect with end-users.	Get feedback	Perform initial vision document.	Empathy	Define & devise	Prototype & Validation	Document					
Software Design + Participatory Co-design (ROL2021)	***Te ao Māori (the Māori worldview)***												
	Initial planning	Preparation	Team building	Engagement with whānau	Data Analysis	Design	Implement.	Evaluation	Ongoing rel..ships				
				Participant groups		Participant groups		Participant groups					
SPEAR + Agile (LAP2020)	***SPEAR = Sovereignty, Positionality, Equity, Advocacy, Reciprocity***												
	Select user stories for this release	Breakdown stories to tasks	Plan release	Develop software	Integrate software	Test software	Release software	Evaluate system					
Research-creation Production Cycle (LON2019)	**PRE-PRODUCTION PHASE**					**PRODUCTION PHASE**							
	Project scope	Core narrative	Technical direction	Goals, HR, budget, timeline	Decide Game genre	Game levels	Coding; project files	Game mechanics	Integrate art+sound	Demo Prototype			
System Requirements Specification + SDLC (SIN2018)	Data collection: req. gathering	Data synthesis: data entry documents created	Decision support system: Release of VIS online										
		Partnership values				***Māori cultural norms***				***Impacts***			

Co-design + Kaupapa Māori (TEM2018)	Research proposal	Assembly of research partners	Whakawhanaungatanga, Creating & maintaining relationships	Research team training	Framing the research parameters	Explore community values and aspirations	Concept. solutions	Prototyping	Final agreed prototype	Testing, includes wider community			
		Kaupapa Māori Korowai											
Development and Evaluation Framework (DOB2017)	Concept. & consult.	End-users focus groups	Review guidelines, research evidence, & resources	Develop key messages	Adaptation of key messages for SMS	Expert review (Round 1)	Expert review (Round 2)	Cultural adaptation	Cultural review	Translations	Review	Testing	Implement
User-centred design + Agile + Cooperative Method Development (TEK2017)		***CYCLICAL***											
	Plan user centred design process	Understand and specify the context of use	Specify user req.	Design solutions to meet user req.	Evaluate design against req.	Designed solution meets user req.							
	SCRUM: project management and social flow of stakeholder involvement.												
CAR[17] + Req. Elicitation (ISA2015)	Problem diagnosis	Planning	Action	Observation	Reflection								
Cultural Heritage Serious Game Creation Framework + Game Design (HUA2013)	Data Tier. Input from Educators/ Historians/ Anthrops.	Logic Tier: Input from Educators/ Historians/ Anthrops/ Game designers	Presentation Tier. Input from Educators/ Game designers										
Socially Aware Approach: Action Research + Part. Design (CHE2005)	Diagnosis ... Prototype req.	Action planning. Prototype design	Action implement. Prototype implement.	Action evaluation. Prototype evaluation	Critical reflection								

[17] CAR - Canonical Action Research

Among the models in Table 5, the XP model was the only one that indicated general user participation in the Design and Develop (coding) phase. As the XP model represents all Agile models in this context, user participation is also reflected in the Develop phase of the SPEAR & Agile model presented in Table 13 (LaPensée, 2020). Moreover, it is understood that users are generally involved in the planning and evaluation phases of a life cycle, as shown in Table 5. Therefore, the following processes with UIDs CHE2005, HUA2013, ISA2015, DOB2017, SIN2018, and LON2019 are presented as having Indigenous users participate in the plan and evaluate phase, as shown in Table 13.

After mapping the steps of the 11 integrated software development processes, I further analysed them to determine which steps present the participation of Indigenous users, as shown in Table 13 in the next section.

Summary of Indigenous user participation in software development processes

Here, I summarise the results of the analysis for Indigenous user participation in software development processes previously shown in Table 12.

According to the discussion in Section 3.1 regarding general user participation, there is evidence of user participation in the Design, Release, or Maintenance phases within the models depicted in Table 5. Moreover, users are commonly involved in the Planning and Evaluation phases of the development process. As a baseline, I note that Indigenous users are involved in these phases, as illustrated in Table 13.

Among the models in Table 5, the XP model was the only one that indicated general user participation in the Develop (coding) phase. This participation is also reflected in the Develop phase of the SPEAR & Agile model presented in Table 13 (LaPensée, 2020), as the XP model represents Agile in this context.

Table 13. *Indigenous user participation in software development processes (n=11)*

Phase	**Plan**	**Design**	**Develop**	**Evaluate**	**Release**	**Maintain**
Process model / UID	**I**	**I**	**I**	**I**	**I**	**I**
Design Thinking + Running Lean + Evolutionary + Agile SCRUM (ALA2021)	✓	✓	X	✓		
Software Design + Participatory Co-design (ROL2021)	✓	✓	X	✓		✓

SPEAR + Agile (LAP2020)	✓	X	✓	✓	X	X
Research-creation Production Cycle (LON2019)	✓	x	x	✓		
System Requirements Specification + SDLC (SIN2018)	✓		X		X	
Co-design + Kaupapa Māori (TEM2018)	✓	X	X	✓		
Development and Evaluation Framework (DOB2017)	✓	X	X	✓	X	
User-centred design + Agile + Cooperative Method Development (TEK2017)	✓	X	X	✓	X	
CAR[18] + Req. Elicitation (ISA2015)	✓	X	X	✓		X
Cultural Heritage Serious Game Creation Framework + Game Design (HUA2013)	✓	X	X			
Socially Aware Approach: Action Research + Part. Design (CHE2005)	✓	X	X	✓		X

Note. **I** = Indigenous user participation. ✓ = yes. x = no.

While Table 13 shows that Indigenous users mainly participate in the planning and evaluation phases, we can see that the red highlighted cells indicate that Māori and Indigenous approaches are incorporated into the development process. This acknowledges that Indigenous users, specifically Māori people, are acknowledged for their expertise and that their cultural values contribute to user participation.

3.3 Conclusion

This section concludes this chapter summarising the results from the background and literature review and present the answer to the second research question, RQ2:

How are Māori people acknowledged in software development processes?

The acknowledgement of Māori people varies across all integrated software development processes. Of all the integrated development processes, the planning and evaluation phases of the software development process acknowledge Indigenous

[18] CAR - Canonical Action Research

user participation. The design phase of two processes and the development phase of one process also showed Indigenous user participation.

The software development process incorporates Māori and Indigenous approaches, acknowledging the contributions of Māori and Indigenous people in this process. Māori people are acknowledged for their expertise and for their cultural values, which contribute to user participation.

4 Using Cultural Methods to Develop Software with/for Māori

In this chapter, I address the third research question, RQ3:

How are Māori Software Development Teams using cultural methods?

To answer this question, case studies were conducted. In the following sections, the case study results (Section 4.2), and discussion (Section 4.3) are presented. Lastly, I summarise the chapter and report on the answer to research question 3 (Section 4.4).

Next, the method (Section 4.1) for conducting the case studies is presented.

4.1 Method

Carver, Kendall, Squires, and Post (2007) outline how a case study is a way to gather information by exploring a topic using methods like interviews and self-reporting. I aimed to understand how Māori cultural practices are included in software development, so I interviewed three Māori software development teams. Each team needed to have at least one Māori member present and be familiar with Māori cultural practices to be eligible for the study.

Recruiting participants

Following ethics approval (Appendix E), the recruitment process involved connecting with teams with previous and ongoing relationships with the research supervisors. The focus was on recruiting teams in the North Island of Aotearoa New Zealand for ease of communication. Consequently, several teams were contacted, with three available to participate in the study.

To start a conversation with the teams, one of the supervisors emailed a team member to introduce me as the researcher. This team member will act as the team's champion. I will then send a follow-up email to introduce myself, explain how to participate, and include necessary documents like participation and consent forms.

Finding Māori software development teams was challenging. As a result, I had to also consider teams that developed software as part of educational programs in computing and graphic design. The teams had the choice to remain anonymous. Two teams were happy to have their work acknowledged, and the third team was unsure. Therefore, I kept their details anonymous.

Engagement

Tikanga Māori (Māori cultural methods) was embraced as part of the process when engaging with participants during the case studies. The four Tikanga Māori principles (TMP): whanaungatanga (building relationships), manaakitanga (respect and hospitality), kaitiakitanga (protection of the gathered data), and rangatiratanga (management and conflict resolution) underpin and guide the engagement process. Furthermore, the engagement process adopts the Values of Research Conduct (VRC), as shown in Table 14 (previously listed in Section 2.2).

Table 14. *Values of Research Conduct (VRC)*

Cultural Values	**Translations**	**Definitions**	**Tikanga Māori**
1. Aroha ki te tangata	Respect people	Allow people to define their own space and meet on their own terms	Whanaungatanga Manaakitanga
2. He kānohi kitea	Meet face-to-face	It is important to meet with the people in-person; a face known to and seen in the community	Whanaungatanga Manaakitanga
3. Titiro, whakarongo … korero	Look, listen … speak	Develop an understanding in finding a place from which to speak	Whanaungatanga Manaakitanga
4. Manaaki ki te tangata	Serve the people	Be caring, sharing, hosting, generous	Manaakitanga Kaitiakitanga
5. Kia tupato	Be cautious	Be polite, culturally safe, and reflective about insider/outsider status	Kaitiakitanga Rangatiratanga
6. Kaua e takahia te mana o te tangata	Do not trample over the mana of the people	Always uphold the 'mana' and dignity of the people	Kaitiakitanga Rangatiratanga
7. Kaua e mahaki	Do not flaunt your knowledge	Be humble - find ways of sharing the knowledge	Whanaungatanga Manaakitanga Kaitiakitanga Rangatiratanga

Note: Adapted from *Decolonising methodologies: research and Indigenous peoples* (p. 120), by Smith (2012) and *Claiming Interstitial Space for Multicultural, Transdisciplinary Research Through Community-up Values* (p. 40), by Cram & Philips (2012).

The second value, ‘He kānohi kitea’, reminds us of that meeting with people face-to-face is important (Smith, 2012). Face-to-face communication allows us to observe non-verbal behaviour and helps build lasting relationships and connections. While face-to-face gatherings are essential, kai (food) is too. In Tikanga Māori, kai is necessary for coming together, easing the conversation, and giving back to the participants for their time and consideration. Next, I discuss the engagement process with participants based on a Whiriwhiri Whakaaro setting. For online engagement, I utilised interviews, see details after the next section.

Whiriwhiri Whakaaro

A Whiriwhiri Whakaaro is a group discussion session designed to provoke deep-level thinking, such as a “Thought Space Wānanga” (Smith, Pihama, Cameron, Mataki, Morgan & Te Nana, 2019). A Whiriwhiri Whakaaro requires two or more participants and takes 1-2 hours. I conduct these sessions in-person and kai is provided. The structure of a Whiriwhiri Whakaaro was designed as follows:

1. karakia tīmata (blessing to open the session),
2. whanaungatanga (building relationships),
3. kōrero (talk, discussion),
4. karakia mutunga (blessing to close the session),
5. kai (food).

During kōrero, the researcher will use the following themes to prompt discussion from the participants:

- team/company background,
- project/s and Indigenous participation,
- Māori/Indigenous perception in software development including team culture
- software development; software apps, processes and teams, and
- cultural methods

At the end of the Whiriwhiri Whakaaro, I will thank the participants for their responses, close the session, and invite the participants to eat following karakia mō te kai (blessing for the food).

Interviews

A semi-structured process will be followed during an online interview (Easwaramoorthy & Zarinpoush, 2006) and will take 1 hour with at most 3 team members present including the researcher. The participant's will be asked to choose an online conferencing application, and the researcher will make the necessary arrangements. Following Tikanga Māori (Māori cultural methods), the researcher will open the interview with karakia (blessing). After signing off ethical forms and a quick round of whakatakinga (introductions), the researcher will use predetermined questions to guide the interview. When complete, the researcher will thank the participants for their responses and close the session with karakia. In contrast to a Whiriwhiri Whakaaro, whakatakinga replaces whanaungatanga (building relationships) and kai is not provided.

Capturing the data

I took written notes and used a Dictaphone to capture audio data during Whiriwhiri Whakaaro. Other devices and apps (mobile phone camera recording, flip video, and/or Zoom app) were used as backup should the Dictaphone fail to capture the audio. Following transcription of the data, the backup recordings were deleted. After the session, the written notes were transcribed to a digital document and along with one valid audio recording, were stored in a Google Drive repository. The Zoom video conferencing app was used to record online Interviews, and the Zoom files were also stored in the Google Drive repository. The stored data was then used later for analysis.

Case study structure questions

I planned to ask the following questions to collect data for the case studies.

RQ3: *How are Māori Software Development Teams using cultural methods?*
Team: 1. How and why was this "Team" formed? *Project / Work / Uni / Club* 2. What are the roles and ethnicity of each member of the "Team"?
Projects: *You mentioned _____ project …* 3. Can you tell me more about the project? *If no mention of projects …* 4. What projects are you working on? 5. Have you worked on projects that have involved Māori and/or Indigenous people from the wider community (users/testers, clients/customers, etc.)?

Māori/Indigenous:

6. How would you describe the term Indigenous?
7. How would you describe a Māori/Indigenous (SD) team?
8. Would a Māori/Indigenous team only include Māori/Indigenous members?
9. Could you say that this team is a Māori/Indigenous team?
    - So, you're saying _____, can you explain further …

Software development:

10. How would you describe a Māori/Indigenous Software Development team?
11. How would you describe Software Development (SD) & a SD/D Process?
    - What is Software? What is Development? What is a SD/D Process?

Cultural methods:

12. How would you describe Cultural Methods (CM)?
13. Would it be expected that a Māori/Indigenous team practice CM in their development process?
    - What does/would this look like?
14. Do you use CM in your SD / Development Process?
15. How does CM improve the SD process?

4.2 Results

In this section I will present the results of the analysed data collected from each case study of which I carried out Whiriwhiri Whakaaro (group discussion sessions) with the following development teams: STEMM team (anonymised), Te Hiku Media, and Digital Natives Academy.

STEMM team

The first team I met with was a team focussed on increasing Māori numbers in the STEMM workforce. This team mentors rangatahi (youth, i.e. high school students) through STEMM subjects (Science, Technology, Engineering, Mathematics, Mātauranga - Māori knowledge), preparing them for university and/or ICT-related jobs. This team is keen to learn and openly practice Tikanga (Māori cultural methods) and Te Reo Māori (the Māori language).

The STEMM team was established by a doctoral student at Massey University in 2016. The student saw that Māori people were lacking in the STEM workforce and created a programme to address this need. The STEMM team engaged with several tertiary institutions over the years. One such recent collaboration is with the University of Waikato, where the STEMM team delivers their programme across the Waikato

region. Two members represent the STEMM team in this case study: Participant 1 (P1) and Participant 2 (P2).

Whiriwhiri Whakaaro setting

The first Whiriwhiri Whakaaro was conducted in July 2023 with the STEMM team. I met with P1 and P2 in one of the meeting rooms at the STEMM teams' workplace.

By adhering to two of the Values of Research Conduct (VRC): 1. Aroha ki te tangata - Respect the people, and 4. Manaaki ki te tangata - Serve the people, as previously shown in Table 14 (Section 4.1), and as a sign of respect, I considered the participants' welfare by preparing the room for their arrival. Arriving 30 minutes before the session, I familiarised myself with the space. Walking through the door to the meeting room, I saw two walls lined with windows that met at a corner. Although the sun shone this morning, the room was colder than anticipated. The sunlight filled the room once the curtains were opened, but it still felt cold. Turning the wall heater on, I left it long enough to warm the room, remembering to turn it off just before the participants arrived. The room was cosy now but not overheated so that it would cause discomfort. In the centre of the room was a large rectangular table with chairs placed around it. There were markers available, and a whiteboard was on the wall, where I used a marker to write an outline of the session. The outline was to keep the conversation on track and on time.

I greeted the participants at the door and welcomed them in. They took a seat opposite me, and we exchanged small talk. Before the main discussion, the consent form was discussed and signed. At this stage, the STEMM team expressed their concerns about anonymity and would be in touch after they obtained permission from their managers for me to use their details in the write-up of this thesis. However, the follow-up remained unresolved, so in this case, I referred to VRC: 6. Kaua e takahia te mana o te tangata - Do not trample over the mana of the people and respectfully exclude the STEMM teams' details from the writing.

Being mindful of the four VRCs: (3) Titiro, whakarongo, … korero - Look, listen, … speak, (5) Kia tupato - Be careful, (6) Kaua e takahia te mana o te tangata - Do not trample over the mana of the people, and (7) Kaua e māhaki - Do not flaunt your knowledge; I had to be careful and check myself throughout the conversation to avoid

speaking over the participants - let them have their say, listen, and then talk. They can share and ask questions, recognisant of their experiences and knowledge.

Relevant to VRC: (1) Aroha ki te tangata - respect the people, and as a Māori myself, I knew it was only right to ask the participants if they would open our Whiriwhiri Whakaaro with karakia (blessing); both agreed for me to do it instead. After the blessing, the team was happy to continue and leave the kai (food) till the end of the session. I proceeded with whanaungatanga (building relationships). We each took turn, saying where we come from, what our interests are, and what brings us to where we are today. Interestingly, we enjoy playing computer games, and P2 and I taught ourselves to program 'code' at a young age. We then realised we had similar interests, and the discussion that followed was less strained and set the tone for being open and relatable. After getting to know each other, I moved on to the next topic, asking P1 and P2 if they could talk about the company they work for, its background, how it came to be, what its purpose is, past and current projects they were involved in, and those that involved Indigenous people.

Roles and Responsibilities

I asked the participants about their roles and responsibilities. Participant 1 (P1) was the STEMM team's Lead Project Manager of Digital Technologies. He was responsible for leading the development of digital technology activities. There were 7 activities in all; they were planned out, each guided by its own pūrākau (Māori narrative). P1 also led one of the 7 activities that required a software game to be developed based on a local iwi pūrākau (Māori tribal narrative). At that time, P1 struggled to find Māori game developers to help on the project. So, he sourced an external programmer to develop the game, an acquaintance of his, a non-Māori programmer.

Although Participant 2 (P2) was the first choice for developing the game for P1's project because of his background in programming and his work with the STEMM team, he was otherwise unavailable. P2's role in the STEMM team was the Kaihautu (Regional Lead Mentor) and was responsible for mentoring students in STEMM subjects at the local high schools. His role focused on delivering STEMM-related activities and helping students succeed in those subjects.

The sole focus of the STEMM team is to enhance the STEMM Kaupapa by recognising Mātauranga Māori alongside traditional STEM disciplines and encouraging student engagement by delivering activities that will continue to pique student interest in STEMM subjects. Moreover, they provide ongoing support to increase student achievement and success, aiming to close the gap on the lack of Māori people in the STEM workforce.

Indigenous Software Development Team

Next, I asked P1 and P2 about their understanding of Indigenous Software Development Teams and whether they consider themselves as such. Although elements of software development were one part of the activities in their STEMM programme, and P2 is an avid programmer 'coder', the STEMM team consider themselves an Indigenous team. They do not think of themselves as a Software Development team.

> P1 ["*We're not, not an Indigenous team that's doing everything perfectly, but we're certainly what I would call ... An Indigenous team*"]

The STEMM team draws on the expression 'by Māori, with Māori, for Māori' (Smith, 2012). P1 and P2 whakapapa (genealogy) and identify as Māori, their other team members are Māori, and they work for Māori, specifically Māori students. They also collaborate with other Māori companies and teams. Although a non-Māori developer developed the pūrākau game, the project itself was Māori-led, and all other collaborators involved in the project were Māori. The game testers, a nephew of P1, and the nephew's friends were all Māori.

Cultural Methods

Participant 1 (P1) and Participant 2 (P2) whakapapa and identify as Māori of Aotearoa New Zealand. As Māori descendants and because of their, P1 and P2 find that speaking Te Reo Māori is an ongoing struggle, which I struggle with too. Both participants were firm about getting more lessons in Te Reo Māori and learning about Tikanga (Māori cultural methods). While P1 and P2 are familiar with Tikanga Māori, they do not openly practise but join in whenever the opportunities arise and keenly observe leaders who do.

> P1["*We are not experts; we tried to listen as much as we could to those who were involved and who had authority*"]

Although P1 could not specifically name any Māori cultural methods, he described *whakawhanaungatanga*, a Tikanga principle, and *kānohi i kitea*, a Value of Research Conduct (VRC) as,

> P1 ["*If we're going to be using your pūrākau, I want to meet with you. I want to get to know you. You get to know me. You get to know what the kaupapa is and then once we know each other, then I want to receive it. Verbally, the way that it was handed down*"]

The Māori term for "the transactional process of receiving historical pūrākau from iwi" was not known to any of us at the time. However, I did manage to find *taonga tuku iho*, which closely represents the statement and translates to "treasures handed down from our ancestors" (Ellis, 2016, p. 438). However, the traditional transaction or the Māori protocol for receiving treasure like pūrākau needs further explanation, such as how should the pūrākau be received, i.e. written down and handed over, delivered by the kaumatua via kōrero, or shared by the tribe at a gathering, etc.

Te Hiku Media

The second team I met with, are dedicated in the revitalisation of Tikanga and Te Reo Māori. Each team member has specific skills that contribute to the development of Te Reo Māori programming interfaces, speech recognition models and transcription tools. This team's company values are imbued in Tikanga Māori (Māori cultural methods).

Te Hiku Media was established in 1990 due to the Waitangi Tribunal's claims around radio spectrum allocation and broadcasting of radio media. In the context of the Wai 262 claim, five Iwi of the far north formed Te Reo Irirangi o Te Hiku o Te Ika; they are Ngāti Kuri, Te Aupouri, Ngai Takoto, Te Rarawa and Ngāti Kahu. Consequently, Te Hiku Media is an iwi communications hub for iwi radio, online television and media services. Four members from Te Hiku Media agreed to participate in this study; in the end, I met with three of them at their Wellington office: Western, Lee and Caleb.

Whiriwhiri Whakaaro setting

Our session occurred in September 2023. Although driving to Wellington was daunting, it was exciting at the same time. Luckily, I used Google Maps and made it to the office with time to spare. Western made his way over to me with the team in tow. They greeted me in a familiar Māori way, handshakes with hugs, then showed me to their communal area. Following a brief whanaungatanga (building relationships), coffee and biscuits, we moved to another room to begin the session so as not to interrupt the rest of the office. Before I started, I reminded the team that kai was provided for, and all agreed we would wait till the end of the session to eat and reflect on the process.

The room we occupied was accommodating: four chairs, a table, and a TV monitor braced to a wall, to which I sat opposite with a glass wall at my back. Māori motifs bordered the reddish-orange-coloured walls, and the air conditioner kept a moderately cool temp, which was very pleasant on this warm Friday morning. The Māori motifs gave off an Indigenous vibe making me feel inclusive and hearing the kōrero (discussion) and kata (laughter) of other teams discussing their mahi (work) made the office space feel warm and inviting. I thought, what a wonderful place to work! Western and his team commented on how fortunate they are in co-sharing a space with other Indigenous teams. Sharing a space with others who have similar principles and values encourages them to practise their cultural values openly and freely. Meeting the Te Hiku Media team at their workplace proved a very comfortable experience.

Roles and Responsibilities

I was excited to learn more about each team member; where they were from, what they did and how they came to be at Te Hiku Media. All three members are ethnically diverse: Māori, Fijian, and Pākehā.

A descendant of Ngāti Awa, Western grew up around the South Waikato. He moved to Hamilton to obtain a bachelor's degree at the University of Waikato. After university, he took a job at Vodafone in Wellington. Western then landed the role of DevOps Engineer at Te Hiku Media, where he manages a suite of tools the company uses for training, deployment, and production. He is also responsible for the kaitiakitanga (guardianship) and maintenance of Oranganui, the company's supercomputer in Kaitaia. Also, overseeing and managing the digital infrastructure for the Papa Reo

Application Programming Interface (API), Western ensures the Kubernetes cluster functions. He checks it can serve requests, handle auto-scaling and load balancing, etc. At the time of our meeting, Western was responsible for moving the Kaituhi tool to the new, New Zealand-based cloud provider. Most of his time is spent trying to speed up the deployment process.

Lee is Fijian and of Pacific Island descent. As a Data Scientist for Te Hiku Media, he works on projects such as Pronunciation Scoring, which scans for correct or incorrect pronouncing of Te Reo Māori syllables and assigns a score for speech recognition - speech to text via transcribing audio. Lee also worked on building the bilingual speech recognition model that recognises Aotearoa New Zealand English and English with Aotearoa New Zealand axioms. Some of the current models out there that transcribe English do not recognise the Kiwi accent or slang. So, his model listens to a conversation in Te Reo Māori and English, and it prompts which language will be spoken next. Lee calls this 'code-switching' (like switching between languages mid-sentence). Currently, he is working on a prototype that can do that. Lee works closely with everyone on the team.

Caleb is Pākehā and of European descent. His role as a web developer involves building apps that consume the models and APIs that Western and Lee work on. Caleb is responsible for the design and Web development of the Kaituhi tool, a transcription app. The app allows an audio file to be uploaded, and the models process it and return the text, which can then be exported via various formats. He also checks that the User Interface (UI) and exporters are working correctly, maintains the folders and teams, assigns workflows and tracks the status of an application, i.e. who is working on a transcription, has it been viewed by a human reviewer, etc. At the time, Caleb was working on a tool that assists the workflow of checks; one person transcribes using the Automatic Speech Recognition (ASR), amends any mistakes that the ASR might have made, and then gets a language expert (Te Hiku Media manager) to check and make sure that the amendments are correct and signs it off.

Indigenous Software Development Team

After learning of the team's roles and responsibilities, I asked them if they know the concept of an "Indigenous Software Development Team". The idea was to discover the team's understanding of the term Indigenous and what it means to them as

developers of Indigenous tools. Western and his team agreed that Indigenous means "the original people who are native to a continent, country, place or land". "I use the word Tangata Whenua here in NZ", Western said. Many Indigenous groups worldwide collaborate with Te Hiku Media, such as the people of Hawaii. The team also commented that they do not think of themselves as an Indigenous Software Development Team but consider themselves to be an Indigenously led DevOps Team (Development Operations).

> Caleb ["*Like there's lots of Māori people, but like, Lee and myself are not Māori" "... you might be an Indigenous person that hasn't got the connection to the Indigenous culture. And you may have Indigenous culture, but not the Tangata Whenua kind of thing*"]

Cultural Methods

When I asked Western and his team, "How would you describe Cultural Methods?" each had their own perspective on the question, prompting with Māori terms and ways of doing things such as mana motuhake (self-determination) and Māori motuhake (Indigenous sovereignty), whaikōrero (formal speech), whakapapa, and karakia. In the end, Caleb reached a singular term describing cultural methods, to which the team agreed in unison.

> Caleb ["*I can guess, I assume it's about Tikanga, um or at least like within the Māori context*"]

Tikanga (Māori cultural methods) is imbued in the Te Hiku Media company values, and the company leaders encourage their staff to uphold those values. Following this ethos, Caleb continued to say that Tikanga is fed into their everyday work activities, like during stand up (daily briefings) they open hui (meetings) with karakia and mihi (greetings). Being the Pākehā of the team, Caleb added that the company also provides professional development in the areas of personal and cultural growth, offering them noho marae (overnight stay at a Māori meeting ground) and/or marae wānanga (workshop at a Māori meeting ground). These opportunities allow staff to learn Tikanga Māori (Māori cultural methods) and experience as much Māori culture as possible at noho marae.

Digital Natives Academy (DNA)

The third team I met with, are determined in providing Māori, whānau (family and extended family) and rangatahi (youth), with IT skills throughout Aotearoa New Zealand. This team actively engage Te ao Māori (the Māori worldview) and openly practise Te Reo Māori and Tikanga (Māori cultural methods) in their daily activities.

In 2014, Rotorua couple Potaua and Nikolasa Biasiny-Tule established the Digital Natives Academy or DNA. The early 2000s saw little to no skills in IT for Māori whanau (family), and the lack of computer access for Māori rangatahi (youth) in Rotorua at the time proved the gap in the digital divide for Māori was evident. The idea of DNA is to inspire and transform the next generation of innovators and digital leaders. By opening their doors and offering communities free access to computers and the Internet, DNA actively bridges the gap and staircases rangatahi into IT jobs. DNA aims to create an ecosystem providing young Māori innovators and creators a seamless transition from instruction to industry. DNA also has other digital hubs that service the wider Māori communities, one in Opotiki, Te Wairoa, New Plymouth, Otautahi, and Papakura. Both Potaua and Nikolasa agreed to meet with me.

Whiriwhiri Whakaaro setting

The Digital Natives Academy (DNA) headquarters is based in Rotorua, and originating from there, I was familiar with the area. I arrived early, with Potaua and Nikolasa shortly arriving after me. Looking familiarly at each other, we shook hands and hugged. At this point, Nikolasa had another engagement and would join us as soon as possible. I was given a brief tour of the building, and although it was a digital space, the building reflected a homely feeling, with couches dotted around and people sitting and talking. The greenery and wood panelling gave a natural aesthetic, much like the realm of Tāne Mahuta (Atua, God of the forest), which is not surprising as DNA incorporates Ātuatanga (connecting to deity) in their pūrākau and creativeness. Although a typical meeting room; table, chairs, and a whiteboard, this one came with a beautiful selection of kai and inu (drink). I was surprised, as I had said I would provide refreshments. However, because Potaua said I was their manuhiri (guest), DNA arranged for the kai. Ethically, does this breach the rules of engagement? Even so, coming home and being treated as a guest was rather nice indeed.

Roles & Responsibilities

DNA take pride in Te ao Māori (the Māori worldview) and encourage it to be at the forefront of their teaching and learning. Potaua, of Ngāti Whakaue, Ngāti Pikiao, Te Whakatōhea, Tuhoe, and Niue, and Nikolasa of Ngāi Tahu are very strong about training and hiring Tangata Whenua (Māori people). They maintain their creators pursue jobs in businesses owned and run by Tangata Whenua in keeping true to their cultural values and training. While most Digital Creative businesses, including Māori-owned/led, are situated outside the Rotorua area. Some DNA students find it hard to leave, whanau being one of the reasons. Potaua and Nikolasa look at ways they can invest in their students, such as having them work for DNA; one specific Māori student, a mother of four children, showed great potential in drawing. She gained the qualifications through DNA and eventually they hired her full-time. DNA has several Tauiwi (non-Māori) on staff, two from the Philippines and Spain.

Indigenous Software Development Team

While DNA focuses on content creation, illustration, and graphic design, their thoughts about Indigenous Software Development team were not explicitly expressed. However, over time, they expect to build requirements for software development and networking. Furthermore, Potaua mentioned the possibility of a game development team that integrates with the DNA creative and tech teams; there is potential for a crossover project where their pūrākau creations are developed as software, maybe digital games.

Potaua ["... *take my stories and the software and smash them together*"]

DNA is also looking to develop its own student and staff management systems and a system that connects the digital hubs. They are also interested in developing their own Māori cloud service and possibly a data centre with the potential for moving into silicon prefabrication.

Cultural Methods

From the get-go, it was fundamental to Potaua and Nikolasa that Te ao Māori (the Māori worldview) was incorporated into the DNA space, reminding their learners that their tūpuna (ancestors) were always innovators who looked at ways of creating new things with whatever technology available. The DNA ecosystem is envisioned much like whakapapa, where the learners' journey begins at the tree's roots and becomes

the fruit when they leave to work in industry. DNA is the core foundation, helping their learners familiarise themselves with online spaces and how to represent themselves as Māori.

Nikolasa ["*So, go in as Māori, don't leave your Māoriness at the door*"]

The Digital Natives Academy practise Tikanga Māori (Māori cultural methods) in their daily operations. These include, karakia, waiata (song), whanaungatanga (building relationships), and manaakitanga (respect and hospitality). For staff and students fluent in Te Reo Māori, tikanga occurs naturally; it is the essence of everything they do: raranga (weaving), pā harakeke (harvesting flax), taiaha (Māori weapon of war), whakaako me te ako (teaching and learning). Fluent speakers of Te Reo Māori do not use terms like "cultural methods" - Tikanga Māori is Te ao Māori - life.

Nikolasa ["because that's Māori"]

As a learning tool, DNA uses DnD (Dungeons and Dragons learning kit) to teach literacy and numeracy. One way of incorporating cultural methods into the teaching and learning at DNA is incorporating pūrākau (Māori narrative) into a DnD campaign. A pūrākau draws on the history of an iwi (Māori tribe) such as Ngāti Pikiao (Te Arawa iwi - Rotorua). This is one way of teaching their learners the history of a Māori tribe and the tikanga within that tribal area, also depicted in the story.

4.3 Discussion of cultural methods in software development process

In this section, I will discuss the results of the case studies I conducted for the research. In consideration of the literature discussed in chapter 2, I investigated how Māori development teams use cultural methods, particularly in the software development process. I recruited and interviewed three development teams from the Information and Communication Technology (ICT) sector. The first team I engaged with, mentors rangatahi (youth) through STEMM subjects, the second team develop Te Reo Māori transcription tools and more, and the third team offers creative digital and technology training programs that honour and reflect Te ao Māori (the Māori worldview).

Better job outcomes

There are expectations of Māori employees to represent and engage with cultural matters in the workplace. Research by Haar and Brougham (2011) indicates that employees who feel their cultural values are understood tend to experience better job outcomes. However, limited knowledge and inexperience of Tikanga (Māori cultural methods), Te Ao, and Te Reo Māori can lead to a lack of confidence among employees. Only one of the team's related to this issue. Moreover, they are determined to improve their Te Reo Māori skills and increase their knowledge and practise of Tikanga Māori. They also expressed a desire to observe others practising these customs as part of their learning process. The other two teams, while a variance in Tikanga and Te Reo Māori skills, were both confident in their knowledge and continual practice of cultural methods, especially in their workplace.

Shaping research methods

Tikanga Māori plays a significant role in Māori-led initiatives and shapes research methods (Jones, Crengle & McCreanor, 2006). The case study revealed that the three teams are familiar with Tikanga Māori, including karakia (blessings) and whanaungatanga (building relationships). One team emphasised the importance of strong leadership in promoting the practice of Tikanga, Te Ao and Te Reo Māori. They noted that their leaders actively encourage professional development and provide the necessary support for growth. In addition, the team attends noho marae (overnight stay at a Māori meeting place) and engages in marae wānanga (workshop at a Māori meeting ground) to learn about Tikanga and Te ao Māori. Another team integrates cultural methods into their teaching and learning by incorporating pūrākau (Māori narratives) into literacy and numeracy tools. The pūrākau provides a cultural history of an iwi (tribe), thereby educating their students in Tikanga Māori.

Indigenous or Māori - Software Development Team, or not?!

The level of skill and use of Māori cultural methods varied across the three development teams. While all three were familiar with them, two teams embrace and practise cultural methods in their daily operations, and the other team, although not yet confident enough to openly practice cultural methods, wants to improve their cultural skills. All three teams do not consider themselves a Māori Software Development team. One team admits they are an Indigenous team. One says they are an Indigenously led team. Moreover, the other team did not state whether they

identified as an Indigenous Software Development team, but instead expressed their ideas on future projects, including software development. While two of the three teams had some involvement in one or more software development projects, one team had more experience than the other, but both teams do not consider themselves a software development team.

4.4 Summary of development teams using cultural methods

In this section, I summarise the results from the case studies and present the answer to the third research question, RQ3:

How are Māori Software Development teams using cultural methods?

The three case study development teams are involved in developments, software or not. Additionally, these teams use cultural methods in their workday, including but not limited to: karakia - to bless the day, hui, kai; mihi - to greet their manuhiri, waiata - to express a sense of community and cultural belonging; whanaungatanga - to build relationships; manaakitanga - to respect and care for others, and pūrākau - to share cultural narrative.

5 Conclusion

This chapter concludes the research and thesis. In the following sections, I reflect on the cultural approach to the case study, a cultural perspective on Software Development research with challenges I faced as a Māori female software development researcher (Section 5.2). Lastly, will discuss future work plans (Section 5.3) and provide some final remarks (Section 5.4).

Next, the answers to the research questions (Section 5.1) is presented.

5.1 Answers to research questions

In this section, I summarise the answers to the research questions as introduced in Chapter 1, and discussed throughout Chapters 2, 3, and 4. These questions guided the exploration for this thesis:

RQ1: *How are Māori cultural methods relevant for software development?*

> Māori cultural methods are relevant for software development because they incorporate Māori knowledge within the research and development process, support initiatives aimed at benefiting Māori people and facilitate the building and maintenance of relationships.

RQ2: *How are Māori people acknowledged in software development processes?*

> Māori people are acknowledged in software development processes through both their expertise and knowledge of their culture.

RQ3: *How are Māori Software Development Teams using cultural methods?*

> The three case study development teams are familiar with cultural methods and consistently engage in karakia - to bless the day, hui, and kai; mihi - to greet their manuhiri; waiata - to express a sense of community and cultural belonging; whanaungatanga - to build relationships; manaakitanga - to respect and care for others, and pūrākau - to share cultural narrative.

5.2 Reflection

In this section, I reflect on the cultural approach to the case studies conducted in this research, including a cultural perspective on software development research and the challenges I faced as a Māori female software development researcher.

A cultural approach to the Case study

Here, I reflect on the approach to the case studies via the four main principles of Tikanga Māori and the seven Values of Research Conduct (Smith, 2012; Cram and Philips, 2012). As shown in Table 15, the Values of Research Conduct are attributes of the principles of Tikanga Māori (Māori cultural methods), which guided the process for recruiting and engaging with participants, conducting Whiriwhiri Whakaaro (group discussion sessions), interviewing, collecting and storing the data, as well as structuring the case study questions.

Table 15. *The 7 VRCs are attributes of the 4 TMPs*

VRC Values of Research Conduct Tikanga **TMP** Māori Principles	1 Aroha ki te tangata (Respect the people)	2 He kānohi kitea (Meet face-to-face)	3 Titiro, whakarongo … korero (Look, listen … speak)	4 Manaaki ki te tangata (Serve the people)	5 Kia tūpato (Be cautious)	6 Kaua e takahia te mana o te tangata (Do not trample over the mana of the people)	7 Kaua e māhaki (Do not flaunt your knowledge)
Whanaungatanga (building relationships)	✓	✓	✓	✓	✓	✓	✓
Manaakitanga (respect and hospitality)	✓	✓	✓	✓	✓	✓	✓
Kaitiakitanga (protection of the gathered data)	✓	x	✓	✓	✓	✓	✓
Rangatiratanga (management and conflict resolution)	✓	✓	✓	✓	✓	✓	✓

Note. A VRC is an attribute of a TMP. ✓ = yes. x = no.

Table 15 shows that one value, VRC2 - he kānohi kitea, does not attribute to TMP3 - kaitiakitanga. During the planning phase, the researcher and participants set the data collection and protection criteria. Once the criteria are set, the researcher is responsible for gathering the data and protecting it. The researcher must promptly address any criteria issues that arise. Therefore, kaitiakitanga is not dependent on face-to-face meetings.

Whakawhanaungatanga (process of creating and maintaining relationships) and whanaungatanga (building relationships), used interchangeably, is a crucial part of the research process. It allows for the time and space to build relationships and creates an environment for open dialogue, where we can speak freely while respecting each other and our backgrounds (Jones et al., 2006). Regarding Tikanga Māori, whanaungatanga (building relationships) invokes the seven Values of Research Conduct, as shown in Table 15. He kanohi kitea (face-to-face) is an important value when establishing relationships (Cram, 2009). Therefore, it was important that I make my way to the participants workplace (VRC1,4). For two of the case studies, I travelled out of town; one of the visits took six hours to get there. I was nervous meeting face-to-face (VRC2) with the teams, but that feeling was short lived. Familial greetings, handshakes and hugs (VRC5), and tours of office spaces made the visits comfortable. Also, it was nice to know I shared common interests with some participants (VRC3,6,7), which helped us connect more deeply. In the three case studies, whanaungatanga (building relationships) was especially important as this activity allowed the researcher and participants to get to know each other and share experiences, thereby establishing a bond - a kinship beyond mere acquaintance (Jones et al., 2006).

Manaakitanga (respect and hospitality), another principle of Tikanga Māori also invokes the seven Values of Research Conduct, as shown in Table 15. “Manaaki ki te tangata” (VRC4) is the value that ensures we care for each other and are careful about how others are treated (Jones et al., 2006). At each opportunity, I asked the participants if they would karakia (blessing), especially at the start of a session (VRC1,2,3,5,6,7). Each session ended with kai (food) and karakia mō te kai (blessing of the food). For two teams, I provided kai. The other team treated me as manuhiri (guest) and provided kai instead. Koha (gift-giving) is essential to manaakitanga. Giving back is one way to care for others, and providing food is a simple yet effective way to reciprocate the participants’ time and input (Cram, 2009; Jones et al., 2006). Also, sharing food is a great way to get further feedback and to get to know each other better. Manaakitanga expresses the nurturing and continuation of the already established relationships and guides how we care for and treat others - manaaki ki te tangata. We, as researchers, invite participants to take part in projects. Therefore, we must take heed and treat our manuhiri with respect and hospitality. One way to show

respect and hospitality is via koha (gift-giving). Koha is the task that shows manaakitanga, and in the three case studies, offering kai as a token of koha reciprocates for the sharing of time and information. Sharing, hosting, and generosity are fundamental to manaakitanga (Cram & Phillips, 2012).

Kaitiakitanga (protection of the gathered data) is a principle of Tikanga Māori that upholds six of the Values of Research Conduct. The second VRC: he kānohi kitea - meet face-to-face, is a value that does not align with this principle. However, it does hold the other six. Regarding one of the case studies, and during whanaungatanga (building relationships), I ensure the team remains anonymous throughout the write-up of this thesis. Additionally, I ensure the details and names of projects for the other two cases are correct (VRC1,3,4,5,7). The main value of this principle is VRC6 or "Kaua e takahia te mana o te tangata (Do not trample over the mana of the people)" (Smith, 2012; Cram & Phillips, 2017). Kaitiakitanga is commonly known as guardianship, or in the context of this research, protection of the gathered data. This principle safeguards the data and upholds the mana and goodwill within the relationship. More importantly, "how will the data be protected from inappropriate use?" (Hudson, Anderson, Dewes, Temara, Whaanga & Roa, 2017, p. 70).

Rangatiratanga is known as sovereignty or self-determination. I define rangatiratanga as the principle underpinning management and conflict resolution in this research. A principle of Tikanga Māori upholds all seven Research Conduct Values, as indicated in Table 15. This principle is related to the management tasks surrounding the case studies, such that I arrived early to setup the rooms, organise food and perform other duties (VRC1, 2, 4, 5). The participants were able to freely share their thoughts and experiences, and I, being mindful not to take over the kōrero (discussion).

A cultural perspective on Software Development research

Culture is a complex concept that varies in perception among individuals. It is often discussed in various contexts, sometimes leading to misunderstandings that need clarification (Tucker, 1996). Furthermore, Indigenous cultures believe that all life, the environment, and the cosmos are interconnected (Lee & Armstrong, 1995). Such that the 'People are the land, and the land is the people' (Durie, 2004; Graham, 2005; Rossouw, 2008), and 'We are the river, the river is us' (Durie, 2004; Rossouw, 2008; Kingi, Durie, Elder, Tapsell, Lawrence, and Bennett, 2018). Ryan and Crotts (1997)

discuss Māori cosmology, highlighting Māori principles and values that foster a sense of belonging within their communities. Thus, adopting a Māori cultural perspective means viewing the world holistically and recognising that everything is intrinsically connected.

Māori, the Indigenous people of Aotearoa New Zealand, have long since utilised computing technologies to connect with Te Reo Māori, whakapapa (genealogy), whānau (family and extended family), and mātauranga (Māori knowledge) (Whaanga, Keegan, and Hudson, 2023). Furthermore, the ubiquity of computing technologies today, requires methodologies to create them and must address the needs of the target users. Consequently, software designed to meet the needs of Māori people requires several approaches: at least an upper-intermediate level of fluency in Te Reo Māori, knowledge of and lived experience in Tikanga and Te ao Māori (the Māori worldview), understanding of Kaupapa Māori Research (KMR) and Te Tiriti o Waitangi, and an understanding of software design and development.

While confident in my knowledge of ICT and Software Engineering, I aim to develop further skills in integrating Māori cultural methods, principles, and values into the software development process. During Whiriwhiri Whakaaro (group discussion sessions) with the case study teams, I drew on my knowledge and experience as a person of Māori descent, including the Tikanga Māori and Values of Research Conduct outlined by Smith (2012) and Cram & Philips (2012). As it was my first time applying an Indigenous approach to Software Development research and interviewing Indigenous and/or Māori-led teams in Industry, I felt nervous and lacked confidence. Although I have a basic level of Te Reo Māori (the Māori language), I was hesitant to converse with fluent speakers, as I struggled to comprehend lengthy conversations or answer complex questions. After whanaungatanga (building relationships) and getting to know each participant better, I revealed I was not fluent in Te Reo Māori. To my relief, some of them shared the same limitation and mutual enthusiasm to improve culturally. Although we spoke some kupu (Māori words), our kōrero (discussion) was mainly in English.

After completing the case studies, I became concerned that my limited proficiency in Te Reo Māori may have affected the results. Upon reflection, I believe it has. I now recognise that a higher level of fluency in Te Reo Māori, a greater understanding of

Tikanga, as well as a deeper connection to Te ao Māori (the Māori worldview), is necessary. It is not just about reading and applying these standards but about embodying them. While I was able to use my upbringing of Tikanga Māori, becoming fluent in Te Reo Māori remains a challenge. This study has shown me that simply being Māori is not enough (Smith, 2012; 2015).

As a Māori female Software Development researcher, my journey of embracing Te ao Māori is ongoing. The impact of colonisation on my parents' upbringing resulted in my primarily Eurocentric education. Consequently, writing about software development from a cultural standpoint presents challenges. A brief overview of Māori beliefs cannot capture the depth of the intrinsic experience of Māori culture itself. However, I assert that Māori people view the world and its elements from a holistic and philosophically cosmic perspective. Additionally, approaching software development through a Māori lens means conceptualising the process as an intrinsic and holistic journey. On that note, I conclude my reflection with a promise to improve fluency in Te Reo Māori, practice Tikanga and embrace Te ao Māori (the Māori worldview) whenever possible.

5.3 Future work

This thesis focused on software development, involving Tangata Whenua (Māori people, the indigenous population of Aotearoa New Zealand) and incorporating Tikanga Māori (Māori cultural practices). While this thesis provides valuable insights, the study has some limitations, including its specific context (the work of formal software teams) and its cultural and population scope (which is primarily Māori-focused; the thesis only mentions some Indigenous works, the researcher's basic level of Te Reo Māori). Additionally, the sample size was limited, as it was challenging to recruit Māori software development teams.

This research endeavours to fill this gap by focusing on how the software development process can genuinely involve Indigenous individuals, especially Māori. This approach not only enriches the development process but also ensures that the resultant systems are genuinely reflective of the needs and values of Indigenous communities.

Consequently, further research is needed to explore Indigenous frameworks for the open-source community. The exploration could involve the application of Māori

cultural methods, such as Whiriwhiri Whakaaro (group discussion sessions) with different population groups, implementing a theoretical framework, and expanding the investigation to include other Indigenous populations.

Indigenous frameworks for the open-source community

In the approach to this thesis, I decided not to address open-source software development, as I did not evaluate individuals' coding skills or assess the software and diverse business models that arise from this movement. Since participation in the open-source development process is open to anyone, it may lead to significant coordination challenges. One pathway for future work is to explore the potential for Indigenous frameworks within the open-source community.[19] For instance, Māori frameworks and approaches, such as Kaupapa Māori Research (KMR), could encourage Māori independent and self-taught coders to collaborate with other Māori and Indigenous teams. This collaboration could help enhance Māori capacity and roles in software development.

Training of Māori software developers within culture

This thesis highlights the limitations in cultural skills that may be lacking among Māori researchers and developers. Designing software for and by Māori people necessitates a thorough understanding of relevant skills and approaches. Researchers and developers in this field should possess an upper-intermediate level of fluency in Te Reo Māori, as well as knowledge of and lived experience with Tikanga and Te ao Māori. Additionally, they should possess a strong understanding of Kaupapa Māori Research (KMR) and Te Tiriti o Waitangi, as well as expertise in software design and development. Further research is needed to explore the training of Māori software developers.[20]

5.4 Final remarks

How can we ensure that the software development process is carried out in the most effective way possible and ultimately benefits the users?

We can ensure the software product meets the needs of people, especially Māori and Indigenous individuals, by including them in the entire software development process.

[19] I would like to thank the Thesis examiners for alerting me to this concept.
[20] I would like to thank the Thesis examiners for alerting me to this concept.

At the heart of the matter, we must examine current software development processes more closely to identify potential guidelines for incorporating Indigenous perspectives. Additionally, we need to examine the roles of the people involved in software development to determine how Indigenous people can contribute to better participation in the development process.

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Appendix A - Glossary of Māori terms

Ātuatanga	connecting to deity
hapū	sub-tribe
hau	vital essence (of person, place, or object)
hui	meeting/s, gathering/s
inu	drink, to drink
iwi	Māori tribe
karakia	blessing, prayer, Māori incantation; to invoke spiritual guidance and protection
karakia mō te kai	blessing for the food
karakia mutunga	blessing for closing an event, gathering, hui, etc.)
karakia tīmata	blessing for opening an event, gathering, hui, etc.
kata	laugh, laughter
kaumātua	aged, elderly, old
kaupapa, Kaupapa Māori	Māori principles or set of values, purpose, topic, subject, matter for discussion, customary practice
kōrero	discussion, conversation, speak, talk
kupu	a Māori word, vocabulary, to speak
mana	strength, power
mana motuhake	self-determination, self-governance, autonomy, independence
manaaki	support, take care, look out for
manaakitanga	respect, generosity, kindness, generosity
manatika pāpori	social justice
manuhiri	guest/s, visitor
Māori	Indigenous people and culture of Aotearoa New Zealand
Māori motuhake	Indigenous sovereignty of the Māori people as Tangata Whenua
marae	Māori meeting ground, courtyard

marae wānanga	workshop at a Māori meeting ground
mātauranga	Māori knowledge, wisdom, understanding
mauri	life force, source of emotions
maumahara	memory, to remember, recall, recollect
mihi	greeting/s, acknowledge, thank
mokopuna	infants, children, adolescents, young
noho marae	overnight stay at a Māori meeting place
ngāwari	flexibility
pā harakeke	harvesting flax
Pākehā	English, European, Caucasian, foreign, exotic - introduced from or originating in a foreign country
papahou	treasure box
pepeha	traditional Māori introduction
pūrākau	Māori narrative, story
rāhui	sustainability of food levels
rangatahi	youth, young person
rangatiratanga	leadership, chieftainship, sovereignty, right to exercise authority
raranga	weaving, plait
Rūnanga, Rūnaka	Māori tribal council
taiaha	Māori weapon of war
Tāne Mahuta	Atua, God of the forest and all forest Creatures
taonga tuku iho	treasures handed down from our ancestors
tangata	people
Tangata Whenua	Māori people, the Indigenous population of Aotearoa New Zealand
tapu	sacred, restricted
Tauiwi	non-Māori, European, foreigner
Te ao Māori	the Māori worldview
tikanga, tikaka, Tikanga Māori	Māori cultural methods, customs and practices
tinana	body

Toi Tangata	native, Indigenous person, aborigine
tūpuna	ancestors, grandparents
waiata	song, chant, to express a sense of community and cultural belonging
wairua	spirit, soul
wānanga, wānaka	workshop, to meet and discuss
whaikōrero	formal speech
whakaako me te ako	teaching and learning
whakapapa	genealogy, lineage, descent, family tree
whakarongo	to listen, hear
whakatakinga	introduction/s
whakawhanaungatanga	process of creating and maintaining relationships
whānau	family, extended family
whanaungatanga	relationships, kinship, family connection
wharekai	kitchen, dining room
wharenui	meeting house, ancestral home
Whiriwhiri Whakaaro	group discussion session

IWI	**LOCATION** - Aotearoa New **Zealand**
Te Whakatōhea	Ōpōtiki, Eastern Bay of Plenty
Tuhoe, Ngāi Tuhoe	Te Urewera, Eastern North Island
Ngāi Tahu, Kai Tahu	South Island, South Island
Ngāti Pikiao	Te Arawa, Rotorua
Ngāti Whakaue	Te Arawa, Rotorua

Appendix B – PICO worksheet & Search Strategy Protocol (SSP)

1. Define a research question/s using PICO[21] by identifying:

Population:	users (people other than the development team) involved and/or participated in the software development process
Intervention:	contemporary software development processes and/or models
Comparison:	traditional software development processes and/or models
Outcome:	participation (and involvement) of Indigenous people, particularly Māori, their communities, and their cultural methods in the software development process

Write out the question/s:

The following questions directed the research:

RQ1: *How are Māori cultural methods relevant for software development?*

RQ2: *How are Māori people acknowledged in software development processes?*

RQ3: *How are Māori Software Development Teams using cultural methods?*

2. Type of question/problem:

Highlight one:

Therapy	Prevention	Diagnosis	Etiology	Prognosis

[21] This form is adapted from: Miller, S.A. (2001). PICO worksheet and search strategy. US National Center for Dental Hygiene Research.

3. Type of studies/publications to include in the search:

Check all that apply:

❏ Meta-analysis

❏ Systematic review

❏ Clinical practice guidelines

❏ Randomised controlled trial

✓ Research studies or articles

❏ Case report or series

❏ Research report or other grey literature

4. List of main topics and terms from the RQs to be used in the search:

Topics:

1. Software development process
2. Participation (involvement)
3. Māori people
4. *Category:* traditional and/or contemporary

Terms:

- Software
- Development
- Process*/es/ing
- Method*/s/ology
- Model*/s/ling
- Life cycle*/life-cycle*/s
- Participat*/e/ory
- Involve*/d/s/ment
- Māori
- Indigenous
- User*/s
- People
- Communit*/y/ies
- Cultur*/e/al
- Traditional
- Contemporary

5. Write the search query combinations:

- (software AND development AND process*
- (software AND development AND process* AND method* AND model* AND life cycle* AND life-cycle*
- (software AND development AND process* OR method* OR model* OR life cycle* OR life-cycle*
- AND participation OR participat* AND involve*
- AND participation OR participat* OR involve*
- AND Māori AND Indigenous AND user* AND people
- AND Māori OR Indigenous AND user* AND people
- AND Māori OR Indigenous AND user* OR people
- AND Māori AND Indigenous AND user* AND people AND communit* AND

cultur*

- AND Māori OR Indigenous AND user* AND people AND communit* AND cultur*
- AND Māori OR Indigenous AND user* OR people OR communit* AND cultur*
- AND traditional AND contemporary)
- AND traditional OR contemporary)
-)

6. List any limits that may apply to the search:

Gender:	No limits
Age:	No limits
Year(s) of publication:	1983 to 2023 (40 years)
Language(s):	English

7. List the digital databases and/or libraries you will search:

- ACM: Association for Computing Machinery
- GS: Google Scholar
- IEEE: Institute of Electrical and Electronics Engineering
- SD: Science Direct - Elsevier
- SL: SpringerLink

Appendix C - Systematic Literature Review (SLR) Paper selection

The SLR Paper selection involved searching for relevant papers via online digital libraries and snowballing techniques. The digital libraries were ACM, Google Scholar, IEEE Xplore, ScienceDirect and Springer Link. In Snowballing, a set of papers is required to start the process. The research supervisors recommended the following three documents as the “start set”: Rolleston et al. (2021), Te Morenga et al. (2018), and Siew et al. (2013). In Backward snowballing, I analysed the reference list of each recommended paper. In Forward snowballing, I analysed the citations to each recommended paper. Additionally, I used another search method based on keywords found in the documents resulting from the snowballing procedure. I searched the following keyword strings via Google Scholar to find further documents pertinent to the research question: mHealth Māori, “software development” rural, indigenous digital game.

Quality assessment

Ongoing consultation with the research supervisors ensured the review was evaluated well.

Inclusion criteria

Texts, peer-reviewed articles, journals, and conference proceedings were accepted, based on the following:

- The paper should be accessible.
- Years ranging from 1983 to 2023, inclusive.
    - The 40-year range presents traditional models such as Royce’s (1987) Waterfall model.
- Research that discusses software development and design processes, including software applications, processes, models, etc.
- Research that presents Indigenous (local, national, and international) software developments written in English and/or Te Reo Māori (the Māori language).

Exclusion criteria

Texts and studies were dismissed based on the following:

- Abstract only, ‘unevaluated’ new idea, patent and/or industry standard, and without empirical results, including dictionaries and vocabulary lists.

- Research that is not related to software development and design or does not answer any of the research questions, such as texts on:
    - Programming;
        - handbooks, guides and/or guidelines
        - languages, i.e. Visual Basic, C, C#, C++, Java, etc.
        - online websites, i.e. Tutorialspoint, Stack Overflow, etc.
    - Systems performance, maintenance and testing, etc.

Appendix D - Systematic Literature Review Data collection

The SLR Data collection involved manually collecting and recording the following details from the selected primary papers:

1. UID: Unique identifier (includes: first three letters of first author, and year of publication, such as: VER2019 = (Verbiest et al., 2019). *Note:* different papers by the same first author in the same year will be suffixed with a letter, for example: SIE2011a or SIE2011b.
2. Author: The author(s) and/or affiliation (organisation and country)
3. Title: Title of the paper
4. Year: Year of publication
5. Reference: Full reference of the paper and/or URL/DOI/ISSN/ISBN
6. Discipline: Information Communication Technology (ICT), Health, ICT & Health, and Other
7. Development or Research: Software Application (SAPP), Technological project, Information Technology Framework (ITFW), Health Framework (HFW), Study (user study or theoretical analysis)
8. Methods used: Kaupapa Māori, Co-design, Participatory Design, Model types, Other methods
9. Indigenous stakeholders: developers, researchers, users
10. Steps in a SD process that indicate Indigenous user participation
11. Steps that extend a SD process that integrates Indigenous participation

Appendix E – Ethics Approval for the Case Studies

The University of Waikato
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0800 WAIKATO (924 528)

HECS Human Ethics Committee
Brett Langley
Telephone +64 77 838 4060
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THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

9 May 2023

Ivy Taia
Annika Hinze
Nic Vanderschantz
Alvin Yeo
Donna Campbell

Re: HECS Ethics Approval of Application HREC(HECS)2023#18 "Using Indigenous cultural methods to develop software with/for Indigenous people"

Dear Ivy:

Thank you for submitting your amended application HREC(HECS)2023#18 for ethical approval.

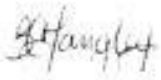
We are pleased to provide formal approval for your project, including the following activities:

- Recruitment of up 21-50 participants for a case study involving software development teams in the central North Island of New Zealand.
- Conduct whiriwhiri whakaaro, interviews and observation sessions with participants. These will focus on their role within their business and/or team, past or current projects that may include software development and/or other ICT development/research, as well as questions regarding Indigenous cultural methods and/or practices.
- Data collection methods are expected to take 1 to 2 hours and may be recorded with consent.
- Participants and organisations can only be named with consent.

Please contact the committee by email (hecs-ethics@waikato.ac.nz) if you wish to make changes to your project as it unfolds, quoting your application number with your future correspondence. Any minor changes or additions to the approved research activities can be handled outside the monthly application cycle.

We wish you all the best with your research.

Kind regards,



Brett Langley, PhD
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