Decolonizing Information Technology Design: A Framework for Integrating Indigenous Knowledge in Design Science Research

Abstract

Design science research focuses on the development of artifacts to solve practical problems in our society and there is a strong emphasis on the justificatory knowledge used to support this effort. However, kernel theories used as part of the justificatory knowledge have predominantly originated from Western worldviews and resulting artifacts have been developed for modern colonial societies. This approach discriminates against and excludes marginalized groups, including Indigenous Peoples. We draw on the Mi'kmaq guiding principle of Two-Eyed Seeing to explore how Indigenous knowledge can be integrated in design science research as justificatory knowledge. We propose a framework to explain the various paths by which Indigenous knowledge integration can be done and provide examples from the literature for each path. Additionally, we present a case study showing how an Indigenous theory for the design of IT artifacts (prescriptive knowledge) can be applied in the creation of a 3D carronade model.

Keywords: Indigenous knowledge, justificatory knowledge, design science research, Two-Eyed Seeing, Kaupapa Māori Modelled IT Artefact

1. Introduction

We cannot decolonize information technology (IT) design if we do not change the way we do research. This paper focuses on the integration of Indigenous knowledge in design science research. Within Indigenous cultures, who one is and where one comes from – relationships – are fundamental to everything. Unfortunately, revealing who we are and where we come from as researchers conflicts with the well-established blind-review process and norms of "objective" academic evaluations. But, let us at least try. We, the authors of this paper, come from two different continents and three largely defined ethnic heritages. One author is an Indigenous Māori person; the others are non-Indigenous people from a country with a deep colonial history. Prior to embarking on this paper, the Indigenous and non-Indigenous authors did not know each other. We came together in a common interest to do information systems (IS) development and design science research better by drawing on the richness of Indigenous knowledge. Along the journey, we discussed and debated ideas, recognizing that we did not always see the issues and path forward with the same "eye." What follows is the fruit of these discussions and our proposal for how IT and IS developers and researchers can move forward.

Centuries of colonialism have left a lasting mark on Indigenous Peoples around the world (Byrne, 2017). Through diverse programs, governments and society attempted to eliminate Indigenous cultures, languages, and traditional knowledge. Purposefully or not, IT has played a role in colonialism. Only 2.2% of workers in Canada's tech industry are Indigenous (Vu et al., 2019) even though they make up 5% of the Canadian population (Statistics Canada, 2022). Similarly, in Aotearoa New Zealand only 4% of the IT workforce are Māori (NZTech, 2021), yet the Māori ethnic population accounts for 17.4% of the national population (Stats NZ, 2022).

There is increasing recognition that IT can be used as a force for positive change, to support sustainable and culturally sensitive (re)development within Indigenous communities and for the benefit of Indigenous Peoples (e.g., Hunter, 2005). As a research paradigm, design science research aims to create new knowledge by developing innovative artifacts that answer questions and solve problems relevant to society (Hevner et al., 2010). As such, it offers a promising way forward to addressing critical issues for Indigenous and marginalized groups.

The term artifact in this context is rooted in the engineering and the sciences of the artificial where it refers to entities that are made by people (Simon, 1970). In the IS discipline, artifacts include constructs like vocabulary and symbols, models as abstractions and representations of reality, methods similar to algorithms and practices, and instantiations, also known as prototypes or implemented software systems (Hevner et al., 2004). As the IS discipline evolved, meta-level artifacts like design theories and principles emerged as valued outputs and serve as theoretical contributions applicable to a broader class of artifacts (Gregor et al., 2020; Gregor & Jones, 2007).

An essential component for artifact development in design science is anchoring in sound underlying knowledge that can explain how designed artifacts achieve their intended outcomes (Goldkuhl, 2004; Kuechler & Vaishnavi, 2012). Gregor and Jones (2007) refer to this underlying knowledge as justificatory knowledge and it can be used *ex ante* to guide how artifacts are designed or developed *ex post* to help explain how a designed artifact works. When justificatory knowledge is used to guide design decisions, it can be drawn from various sources, including tacit knowledge of personal experiences or observations (Benfell, 2021). However, IS research more often borrows justificatory knowledge from formalized theories outside of the IS discipline, like the natural or social sciences, and adapts the theory in the context of the IS domain to serve its purpose. These formalized theories are often referred to as kernel theories (Walls et al., 1992).

While the emphasis on kernel theory use has advanced the rigour and relevance of IS design science research, kernel theories have predominantly originated from Western worldviews and the resulting IT artifacts are developed for colonial societies. This is especially true when theories from the behavioural sciences are used to inform design decisions. Most of the research on human behaviour from psychology assumes that findings from one population can be generalized globally, which is not true in reality (Henrich et al., 2010). In top psychology journals, 96% of participants were from Western industrialized countries, while these countries only made up 12% of the world population (Arnett, 2008). Within IS, most of the commonly used theories in the discipline (listed on the Association for Information Systems' IS Theory Wiki – https://is.theorizeit.org/) were originally developed and published in English (Davison & Díaz Andrade, 2018). The dependency on English highlights a wider issue because "language is more than communication. Above all, it constitutes a way of seeing the world, an entire culture" (Alves & Pozzebon, 2013 p. 630). The end result is that the IS community has marginalized knowledge and theories from non-Western perspectives, including those of Indigenous Peoples in all parts of the world (Myers et al., 2020) and the rich knowledge developed outside of non-Western societies are not used for corroboration, testing, or validation of IT artifacts.

Although Indigenous Peoples may use IT in a similar manner to non-indigenous peoples, how they conceptualize and interact with IT artifacts may be very different (Osei-Bryson & Bailey, 2019). Kernel theories that are anchored in Western worldviews are not necessarily relevant for Indigenous Peoples. The incongruence between the anchoring theories (Western theories) and users (Indigenous Peoples) can lead to design-reality gaps and explains why IT solutions are sometimes perceived as useless or suboptimal and are subsequently abandoned or fail to achieve their goals (Heeks, 2002; Masiero, 2016). An alternative approach calls for integrating Indigenous knowledge into IT artifact design. Although Indigenous knowledge systems have received limited attention in IS and design science (Myers et al., 2020; Osei-Bryson & Bailey, 2019), they can provide rich and unique guidance to research and design.

Outside of IS, a substantial discourse exists around how to integrate Western and Indigenous knowledge systems (Bartlett et al., 2012). It has been noted that both knowledge systems are developed through culture-based methods of experiencing and making sense of the surrounding world. Further both systems have distinct approaches that rely on empirical data, observations, experimental procedures, and knowing of cause-and-effect relationships (Snively & Corsiglia, 2016). Such similarities could be leveraged in a way to enable harmonious and complementary co-application Thus, building on the premise that Indigenous knowledge offers great potential for informing IT artifact design, we ask *how can Indigenous knowledge be integrated as justificatory knowledge in design science research?*

Our exploration of this question draws on the Indigenous Mi'kmaq principle of Two-Eyed Seeing. Two-Eyed Seeing encourages one to view the world through Indigenous knowledge and ways of knowing with one 'eye' and Western knowledge and ways of knowing with the other 'eye' (Bartlett et al., 2012). Informed by this principle, design science practitioners can consider and appreciate the value of Indigenous knowledge as justificatory knowledge in their projects.

Through this work, we address the important topic of decolonizing IT development and IS research (Myers et al., 2020). To design science research, we contribute a framework outlining where and how Indigenous knowledge can be integrated with Western knowledge in the research process and provide examples of how the framework can be applied. In particular, we delve into the *Kaupapa Māori Modelled IT Artefact* model (Shedlock & Hudson, 2022), which represents a form of Indigenous prescriptive knowledge for IT artifact design, and present how the *Kaupapa Māori Modelled IT Artefact* model can be applied when constructing a digital 3D model of a historical artifact.

In Section 2, we provide an overview of the relevant background for this research. We develop the Indigenous Knowledge Integration Framework in Section 3 and present examples of how the three pathways in the framework has been applied in Section 4. In section 5, we apply the *Kaupapa Māori Modelled IT Artefact* model to the case of creating a 3D model of a carronade that resides on the historic battle site of Te Ruapekapeka. The paper concludes in Section 6 with a discussion and conclusion.

2. Background

2.1 Kernel theory use in design science

Walls et al. (1992) first introduced the concept of kernel theories as knowledge from the natural or social sciences that govern the design requirements and as mandatory components of design products and processes. Since then, the concept has evolved with Gregor and Jones (2007) arguing for merging the kernel theories of the product and process into a single concept of justificatory knowledge. Justificatory knowledge extends beyond formalized theories and can include tacit knowledge as well. This knowledge gives a basis and explanation for the design. For theory driven (*ex ante*) design science, the focus has remained on formalized kernel theories to uphold and demonstrate rigour in the project. Thus, kernel theories are now integral to artifact development in the IS discipline because they provide explanatory power to the practical knowledge manifested in the artifact (Goldkuhl, 2004).

Given the importance of kernel theories, research has examined how to use kernel theories and the process of translating kernel theory concepts to (1) meta-level knowledge that can guide design in the IS discipline, or (2) artifacts themselves. Goldkuhl (2004) presents a framework showing how cause-and-effect relationships from kernel theories can be transformed into the design realm. Kuechler and Vaishnavi (2012) provide more detail on how this can be done by suggesting various forms of reasoning that can be applied to kernel theory concepts. While forms of logical reasoning have been suggested, how it is operationalized is still vague. Möller et al. (2022) address this issue by identifying six mechanisms to operationalize kernel theories. First, kernel theories can be used to derive objects of interest, like meta-requirements and design principles. Second, kernel theories can be used as a theoretical lens to analyze or frame data in design science projects. Third, kernel theories can provide explanations for why designed artifacts work. Fourth, kernel theories can be used to refine and improve existing objects of interest. Fifth, in situations where objects of interest are to be adapted, kernel theories can inform the transformation of the objects; for instance, kernel theories can guide the transformation between design requirements and design features. Finally, researchers can employ kernel theories to evaluate objects of interest.

Despite the interest in how to use kernel theories, there is still limited guidance on how to integrate Indigenous knowledges as kernel theory and within design science projects. Of the 47 papers reviewed by Möller et al. (2022), none leveraged Indigenous worldviews or knowledges. This is problematic because the research and design of IT artifacts are blind to a rich knowledge system, that while similar to Western knowledge in some respects, also has important epistemological differences.

2.2 Indigenous knowledge

There is no single definition for Indigenous knowledge and understanding the nature of Indigenous knowledge in a decolonized research is difficult because the definitions have been devised largely from Western perspectives. Battiste and Henderson (2000 p. 42) describe Indigenous knowledge as the "cumulative body of knowledge and beliefs, handed down through generations of cultural transmission, about the relationship of living beings (including humans) with one another and with their environment." Researchers must put aside Western conceptualizations of knowledge and engage with Indigenous knowledge in situ – in the context and relationships in which it was developed and meant to be used (Bastien & Coraiola, forthcoming).

Indigenous Peoples have their own methods for classifying and transmitting knowledge and their knowledge systems are complete with their own concepts of epistemology, scientific and logical validity (Battiste, 2005). Unlike Western science, Indigenous knowledge systems tend to adopt a holistic approach and do not separate observations into distinct disciplines (Iaccarino, 2003). Indigenous knowledge are transcultural, systemic, and adapt to changes in environmental conditions over time (Battiste, 2005). Indigenous knowledge is performative — the product of human movement, actions, practices, and protocols — and are embodied in people, their activities, relationships and in their tools, artifacts, and all forms of technology (Turnbull, 2009). Indigenous knowledge is also inherently tied to land, very broadly defined including the landscapes and ecosystems where the knowledge is developed and shared (Battiste, 2005). Indigenous knowledge is fundamentally relational (Turnbull, 2009), built from relationships first between people and the land, and then between people themselves (Tynan, 2021). Indigenous knowledge systems do not interpret reality following a linear conception of cause-and-effect relationships, but rather a world of multidimensional relationships and a mesh of interactions (Mazzocchi, 2006). Stories and storytelling are essential culturally nuanced ways of knowing among Indigenous communities (Hunt, 2014). Storytellers, knowledge keepers, and elders play an important role in remembering the collective past and transmitting knowledge (Bastien & Coraiola, forthcoming).

The challenge for researchers when they inform the design of an artifact using Indigenous knowledge is the reality that they are only capturing a static, decontextualized portion of that knowledge. Care must be taken to avoid the traps of colonial-based extractivism; that is to selectively extract certain parts of Indigenous knowledge in the quest to produce "original" research (Tynan, 2021). Indigenous knowledge has complementarities to contemporary scientific knowledge (Turnbull, 2009) that could be useful for addressing key challenges. However, in these efforts, the homogenisation and appropriation of Indigenous knowledge within global knowledge systems must be avoided by establishing protocols by which Indigenous knowledge is defined by its producers and keepers, who retain control and protect the autonomy of their knowledges (Turnbull, 2009).

2.3 Two-Eyed Seeing

The Indigenous Mi'kmaq guiding principle of Two-Eyed Seeing emphasizes the harmonious integration of different perspectives and ways of knowing. Mi'kmaq Elder Albert Marshall introduced the principle to encourage students in integrative science to benefit from the "it's us together" perspective that is often needed for collaboration (Bartlett et al., 2012). Two-Eyed Seeing is a gift treasured by Indigenous Peoples through which we learn to see from one eye with the strengths of Indigenous knowledge and from the other eye with the strengths of Western knowledge. In this way, Two-Eyed Seeing acknowledges that Indigenous knowledge is a distinct and complete knowledge system that can operate in parallel with the mainstream Western science (Iwama et al., 2009).

The idea and practice of Two-Eyed Seeing can be hard to convey to academics trained in Western research paradigms because it does not fit into a particular research approach or discipline. Instead, it is a way of life that covers all aspects of one's existence including views on social, economic, and environmental issues (Bartlett et al., 2012). The principle also challenges people to refine their thinking and seek different perspectives. Being able to seamlessly weave between knowledge systems and appreciating the strengths of each one, will enable a more comprehensive understanding of complex issues and the development of universally appropriate and applicable solutions (Wright et al., 2019).

Elder Albert Marshall provided the academic community with four lessons on how to apply Two-Eyed Seeing (Bartlett et al., 2012): (i) acknowledge the authenticity of Indigenous knowledge, that it is not made up and validation by recognized elders and knowledge holders is extremely important; (ii) acknowledge that no one knows everything and each elder and knowledge holder will have their own expertise; (iii) recognize the legitimacy of other forms of knowledge representation beyond book knowledge, including stories, songs, crafts, ceremonies, and connection with the land; and (iv) understand that Indigenous knowledge is acquired over a lifetime and is not akin to a 4-year university degree.

3. Indigenous knowledge integration framework

To develop a framework for the integration of Indigenous knowledge, we adapt Kuechler and Vaishnavi's (2012) framework for theory development in design science research. Their framework spans three operation spaces – moving from (1) kernel theory, to (2) mid-range theories, and then to (3) artifacts. The mid-range theories are conceptual intermediaries between the abstract space of potential solutions suggested in kernel theories and the concrete solutions offered by the artifact. Kuechler and Vaishnavi (2012) define two types of mid-range theories as part of their framework: a design-relevant explanatory/predictive theory and an IS design theory. The former explains why the class of artifacts has the effects it does, while the latter prescribes how the class of artifacts is supposed to behave and how to construct it. These concepts can be seen in the lower half of Figure 1. Additionally, Kuechler and Vaishnavi (2012) describe three paths for integrating kernel theories into design artifacts. First is direct integration where there is no knowledge capture other than what is reflected in the artifact. Second is solely deriving prescriptive knowledge (e.g., design principles) from kernel theories before moving to the artifact. The third is to develop both midrange theory components before moving onto the artifact. Our framework (Figure 1) spans the three similar operation spaces that we have renamed as (1) the knowledge space outside of the design domain, (2) the theoretical space of the design domain, and (3) the instantiation space.

Justificatory knowledge for artifact design is typically found in the knowledge space outside of the design domain. Rather than comprising of only kernel theories from Western science, it also includes Indigenous knowledge. The theoretical space of the design domain contains meta-level knowledge that applies to the broader class of artifacts and is grounded in the knowledge from outside of the design domain. Meta-level knowledge here includes the two types of mid-range theories from the original framework plus Indigenous theories for IT artifact design. The meta-level knowledge from the theoretical space of the

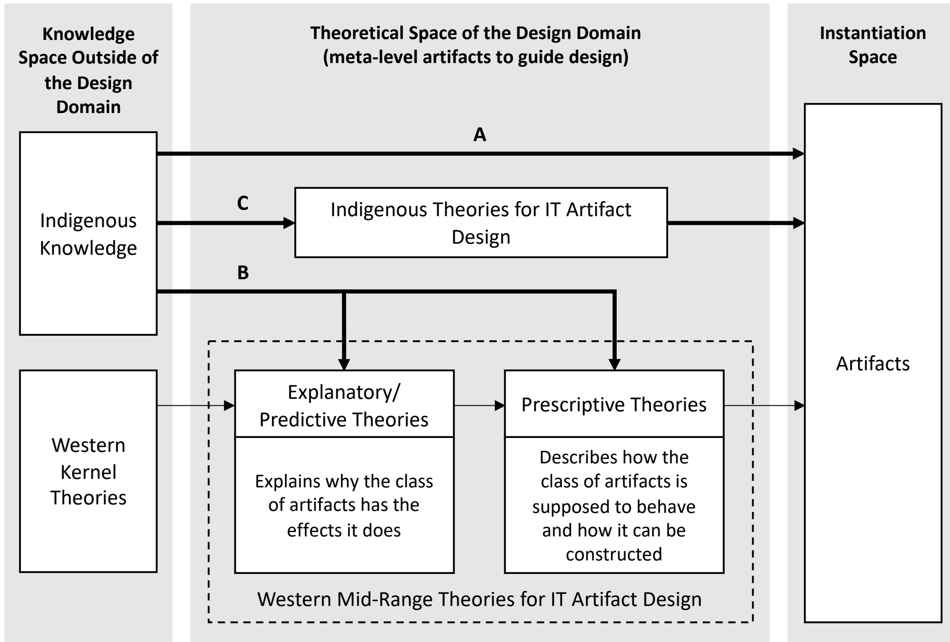

Figure 1: Indigenous knowledge integration framework for design science research

design domain can be instantiated in the instance space, where artifacts are created for specific contexts.

We propose that Indigenous knowledge can be effectively integrated into artifact design in three main ways. The first option is a direct integration as shown with path A where Indigenous knowledge is manifested in the designed artifact. Artifacts developed following this approach will draw on Indigenous knowledge from outside of the IS design domain and integrate it directly in the artifact. This approach can be particularly valuable because Indigenous knowledge is highly contextualized, thus it provides nuances to the resulting artifact that might not be possible for instantiations based solely on Western knowledge, thus ensuring that solutions are highly relevant for end users (Warren & Rajasekaran, 1993).

The second path of integration (path B) draws on Indigenous knowledge to form meta-level artifacts that can help guide the development and design of artifacts. Meta-level artifacts are a contribution in their own right (Gleasure, 2014) and in this path, Indigenous and Western knowledge are integrated at the meta-level. Thus, designed artifacts can then draw on meta-level knowledge that was created with inclusivity in mind and embraces both worldviews.

The third integration path (path C) involves the creation of Indigenous meta-level artifacts, which could include IS design theories that are based on Indigenous knowledge and meant for Indigenous IT artifacts. We refer to this knowledge as Indigenous theories for IT artifact design. The integration with Western knowledge can occur in the instantiation space, however there will be evidence of Indigenous design knowledge created for the broader class of systems. Various forms of Indigenous knowledge have long carried characteristics of what Gregor (2006) refers to as Type V theories – the "how to" knowledge – like how to harvest (e.g., Oneida Indian Nation, 2020). Applied to design science, Indigenous theories for IT artifact design would carry similar characteristics but focus on how to design IT artifacts.

4. Using the framework

To demonstrate how the above framework can be used, we provide three examples from the existing literature that can be described using one of the three paths for Indigenous knowledge integration.

4.1 Path A: Direct use of Indigenous knowledge for artifact development

Akanbi and Masinde (2018) provide an example of a direct integration of Indigenous knowledge in artifact design. The authors developed a drought forecasting system in tribal areas of KwaZulu-Natal, South Africa and drew on the works of Fogwill et al. (2012) to propose that integration of localized Indigenous knowledge can improve the accuracy of the predictions. Local Indigenous knowledge about droughts rely on diverse natural indicators connected with the environment as well as years of experience on the land (Masinde & Bagula, 2011). This study reflects that Indigenous knowledge is highly relational, not just between people, but between people and the land (Tynan, 2021). The authors interviewed local farmers and held focus groups with local Indigenous knowledge holders. The shared Indigenous knowledge was formalized into a semantic structure using an ontology for machine readability, reusability, integration, and interoperability across different systems. The system had inputs from environmental sensors (based on knowledge from Western science) and integrated local Indigenous knowledge. The process leading to a domain ontology for Indigenous knowledge on droughts shows how Indigenous knowledge can be integrated directly into artifacts.

4.2 Path B: Developing and using meta-level artifacts from Indigenous knowledge

An example of path B integration framework comes from the development of design principles for IT artifacts from Steen (2022) based on insights drawn from Kimmerer (2015) emerging outside of the design domain. In the book *Braiding Sweatgrass: Indigenous Wisdom, Scientific Knowledge and the Teaching of Plants*, Kimmerer (2015) shares stories drawn from her experience as an Indigenous scientist (botanist), mother, and woman of the Citizen Potawatomi Nation. Her stories show how other beings – e.g., plants and animals – offer life lessons even if we have neglected them. Her stories emphasize that environmental sustainability requires people to acknowledge and celebrate our relationship with the rest of the living world. A key lesson from Kimmerer's work is the notion of "honorable harvest" of which she writes, "to take only what you need; never take more than half; leave some for others; harvest in a way that minimizes harm; use it respectfully; never waste what you took; share with others; and give thanks for what you have been given" (2015 p. 183). This concept was subsequently adapted by Steen (2022) who used analogical reasoning to move it into the realm of IS design. He suggested guiding principles for data collection where we "take only what we need" and "use it [the data] respectfully." The concept can also be applied for developing fair and open algorithms where we must "minimize harm" and "share with others" (Steen, 2022).

4.3 Path C: Creating Indigenous theories for IT artifact design

An example of path C integration comes from the work of Shedlock and Hudson (2022), who develop the *Kaupapa Māori Modelled IT Artefact* model, a procedure for organizing an Indigenously framed IT artifact, as shown in Figure 2. The procedure starts with a core set of Indigenous dimensions to guide artifact construction that include *framing* of research, *relationships* building, and *engaging* with Indigenous communities during the early planning stages of an IT artifact (Shedlock & Hudson, 2022). The centre of these three dimensions represent the core *connection* aspects of the three other dimensions, while specialized working knowledge remains within each dimension.

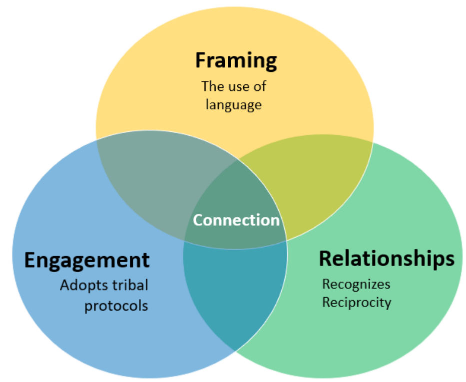

Figure 2: Kaupapa Māori Modelled IT Artefact model

The *framing* dimension considers the intention and means-end motives of the IT artifact, which represents the language linked to identity – "if we want to make sense of a community's identity, we need to look at its language" (Crystal, 2002 p. 39). When a community loses its language, it also loses a great deal of its tribal identity. Thus, aligning language to the instantiation of IT artifacts opens portals for communicating Indigenous priorities in search of heritage knowledge (Salmond, 2012). Language by itself does not address the entire *Kaupapa Māori Modelled IT Artefact* model but is important when identifying the involved parties encompassed to discuss the problem.

The *Kaupapa Māori Modelled IT Artefact* model proposes a relational link that is reliant on the ritual of maintaining accountability to *relationships* as feedback loops during the problem initiation stages of designing the IT artifact. For the IT artifact to be considered as a viable solution to a problem, careful choices must be made in selecting topics, methods of data collection, forms of analysis, and information presentation (Shedlock & Vos, 2018). Relationships within an Indigenous IT artifact paradigm move beyond individual knowledge to shared relational knowledge involving communal interactions as a mode of maintaining relationships of accountability early in the IT artifact lifecycle (Shedlock & Hudson, 2022).

The *engagement* dimension of the *Kaupapa Māori Modelled IT Artefact* model includes the unique characteristics attributed to the Indigenous community concerned as a practice (Shedlock & Hudson, 2022). Often engagement includes ceremony as part of the process to obtain consent to construct the IT artifact. The engagement dimension of the IT artifact construction involves consent (can I?) that deliberates *ex ante* between the reasoning and intended purpose of the IT artifact matched to the Indigenous community. The engagement dimension respects a definition for Indigenous knowledge grounded in an awareness of Indigenous theory for constructing physical artifacts and transferred to the digital universe of IT artifact. The process of engagement adopts tribal protocols that align with well-establish, traditional modes of approval and access to information for constructing the IT artifact (Shedlock & Hudson, 2022).

6. Applying Indigenous meta-level design knowledge: The carronade as a tribal 3D model artifact

In this section, we report on the process of constructing a digital 3D (three dimensional) model of a carronade that has passed the *Kaupapa Māori Modelled IT Artefact* model guidelines for framing tribal language, relationships, and engagement design criteria (Shedlock & Hudson, 2022). The 3D model serves as the artifact of interest in the instantiation space and the *Kaupapa Māori Modelled IT Artefact* model is the Indigenous theory for IT artifact design that guides the creation of the 3D model. Our intention is to demonstrate the importance of, and potential for, Indigenous theories for IT artifact design, thus we do not present the methodological details of this case study. Interested readers can contact the authors for more information.

6.1. The carronade as a tribal treasure

Residing on Te Ruapekapeka Pa site is a carronade depicted in Figure 3. The carronade is linked to the historic battle site of Te Ruapekapeka. Te Ruapekapeka Pa is one of Aotearoa New Zealand's best-preserved and most significant battle sites. In 1846, it was the site of the last battle of the Northern War, where approximately 400 warriors stood against a combined British force of 1600 servicemen and their friendly allies. The warriors purpose-built a pa (fortification), which was cleverly adapted to confront the methods and armaments of European warfare. Prior to the battle, Te Ruki Kawiti (general of the battle) had two of his artillery pieces positioned at the rear of the battle site and the other in a forward position. However, both were damaged early in the battle and rendered ineffective and unusable.

Figure 3: Rebuilt Carronade on the historic Te Ruapekapeka Pa site

During its time, the carronade was considered a technological advancement both on sea and land. A carronade is a short barrel cannon used by the British Royal Navy from the mid-18th century to the mid-19th century. Its main function was to serve as a powerful, short-range weapon aboard sailing vessels, however, it also served as an effective land battle weapon.

In 2009, remnants from one of the artillery pieces at the battle of Te Ruapekapeka that had laid dormant over time was rebuilt. Today, the carronade is a reminder of the final battle of the Northern War between the British Empire and Northern Māori. It is a symbolic relic linked to the actual battle and a time of unsettled change in New Zealand. The carronade is serves as a living representation of those times that have been celebrated, discussed, and deliberated as part of Te Ruapekapeka's story and the historic beginnings of New Zealand.

6.2 The prototyping stages of the 3D model carronade

Creating the 3D model carronade prototype involved five iterations. The process commenced in the first iteration with a low-resolution model to better understand the important tribal requirements. Then, learnings from the prototype development were implemented over three further iterations to improve the experience each time. The fifth iteration viewed the 3D model in different device settings to explore new experiences of the carronade.

The ***first iteration*** of the carronade prototype was the development of a computer aided design (CAD) 3D model using the Blender modelling software. The construction process used a best-guess approach that created a 3D model of the carronade from scratch as a learning iteration. This copy of the 3D model was used to open dialogue with the tribal community of Te Ruapekapeka, listen to their priorities, and observe the tribal characteristics of the community. The goal was to comprehend the relationships that existed within the community and empower the community to ask questions and highlight important aspects of the 3D model carronade.

In working with the Te Ruapekapeka community and applying the *Kaupapa Māori Modelled IT Artefact* model, important points were noted to consider when framing the construction of the 3D model carronade. These included:

- Allowing for intellectual guardianship to be transferred from the physical artifact to the digital 3D model replica.
- Ensuring the level of tribal voice is consistent and accurate when augmenting tribal narratives.
- Keeping the community informed of progress to stay connected to both the community and construction stages of the 3D model artifact.
- Providing a quality experience and making sure there are a variety of digital mediums for the community to experience.
- Valuing the level of trust being assigned to the development team and a deep appreciation for the heritage information provided by the families involved.

The goal was to use the initial prototype as a way to explore the stories linked to the 3D model conveying tribal language within the stories being retold. This first iteration was also a time to identify the guardians of the 3D model artifact and any reporting requirements as part of the relationship principles of the construction process (i.e., who approves each augmentation stage of the 3D model's construction process). In this way, the first iteration was to align with the tribe's Indigenous knowledge requirements, complex construction functions, and provenance reporting guidelines of the digital 3D model. By including the guardians within the process, the accuracy of stories being retold via the 3D model artifact could be enhanced, thus improving the tribal experience when viewing the 3D model.

The next three iterations (iterations 2 through 4) involved field trips to the physical historic pa site to take photos of the carronade using photogrammetry techniques. The images were loaded into Reality Capture – a CAD software for rendering unordered images (see Figure 4).

The ***second iteration*** model looked to extend the first iteration prototype to display more realism. To achieve this, the researchers looked to increase the vertices, edges, and face count of the 3D model with the result being a higher level of realism. Increasing the size of the 3D model to match the assorted device types was a way to improve the quality of the 3D model and community realism experience.

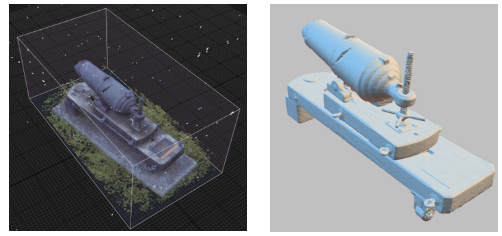

Figure 4: Rendered 3D model in Reality Capture

In the ***third iteration***, the finer details of the carronade were explored again to improve the realism of the 3D model. A close-up inspection of the carronade's architecture such as the broken muzzle and cracks in the under-carriage of the model was undertaken to better define the abnormal parts of the carronade, as these were unique characteristics of the cannon after the battle.

The ***fourth iteration*** was concerned with re-sizing the 3D carronade model for different hardware devices to depict an array of different experiences. This iteration prepareed the 3D model for different devices including the initial tribal narratives and interactions.

The ***fifth iteration*** of the construction process focused on using the carronade model for different purposes. Three copies of the model were instantiated for different devices. The first version was for a mobile phone device using augmented reality to enable users to interact and engage with the carronade. This option responded to a comment made during one of the tribal focus group meetings, "*it would be great to imagine the carronade firing at the British lines.*" Another version of the 3D model was placed on a virtual reality landscape inside an HP Reverb Virtual Reality headset with a similar purpose of firing the 3D model carronade at the British army lines. This option also responded to a further request from the focus group to "*inspect the carronade up-close.*" The third device used was a web server enabling the 3D model carronade to be viewed as a virtual interaction using the internet. Figure 5 shows three versions of the 3D carronade model – the first two are in digital forms and the third is a 3D printed model.

Figure 5: 3D carronade model seen in mobile augmented reality (left), in virtual reality headset (middle), and as 3D printed replica (right)

5. Discussion and conclusion

Decolonizing design science research requires new perspectives and approaches. In this paper, we adopted the guiding principle of Two-Eyed Seeing to propose an Indigenous knowledge integration framework for design science research. The framework shows three paths by which Indigenous knowledge can be integrated as justificatory knowledge in design science research. We show how the framework can be used with three examples from literature – one for each path. Additionally, we provided a case study showing how path C, the creation of Indigenous theories for IT artifact design, can be applied. In the case study, the *Kaupapa Māori Modelled IT Artefact* model was used to guide the creation of a 3D carronade model.

Applied to design science research, Two-Eyed Seeing encourages researchers and IT artifact designers to view the world from multiple perspectives and appreciate the richness of both Indigenous and Western knowledge as viable justificatory knowledge to anchor design decisions. Despite the importance of doing so, the research community must be cautious and attentive not to engage in extractivism where Indigenous knowledge is taken and used (Tynan, 2021) without consideration of the local communities and involvement of knowledge keepers. Integrating Indigenous knowledge in design science must be done respectfully to avoid the misappropriation of knowledge. Thus, researchers must be mindful not to (adapted from Levac et al., 2018):

1. Inappropriately generalize or take things out of context as this can weaken Indigenous traditions.
2. Deny cultural differences just to find commonality among various communities, groups, and traditions.
3. Assimilate Indigenous knowledge into IT design in a manner that it becomes invisible.

IS are modern day artifacts that are cultured-ingrained. The global IT user community will benefit when we design more inclusive solutions. By embracing Two-Eyed Seeing in design science research, Indigenous communities and individuals can, through IT artifacts, reclaim their heritage, revitalize their cultural practices, and forge a path of sustainable development that honours the wisdom of the past while embracing the opportunities of the present.

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