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

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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. 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 explores the value of Indigenous knowledge for 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 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 opportunities 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; Vom Brocke et al., 2020). As such, design science can offer a promising way forward to help address critical issues for Indigenous Peoples by way of creating IT artifacts that can help drive the change needed.

An essential component for artifact development in design science is anchoring in sound underlying knowledge that explains 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. Justificatory knowledge used to guide design decisions can be drawn from various sources including formalized theories, referred to as kernel theories

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(Walls et al., 1992), or tacit knowledge of experiences and observations (Benfell, 2021).

In this paper, we argue that design science research holds promise for addressing critical issues for Indigenous and marginalized groups so long as it appropriately takes into account Indigenous knowledge and context. Thus, our research question asks: *how can Indigenous knowledge be integrated as justificatory knowledge in design science research?* In framing the research this way, we use the term "integration" cautiously, because it has often been used as a euphemism for assimilation, such that Indigenous knowledge is absorbed into Western knowledge systems and becomes invisible. Integration should be done mindfully so that the strengths of each knowledge system can contribute in parallel.

The motivation for our research question stems from recognizing that kernel theories (Walls et al., 1992) in design science research have predominantly originated from Western worldviews and the resulting IT artifacts have been 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 falsely assumes that findings from one population can be generalized globally (Henrich et al., 2010). Due to this assumption, the research suffers from a significant imbalance between sample populations (mostly Western industrialized countries) and the overall world population (Arnett, 2008; Rad et al., 2018). Within IS, most 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). As a result, the IS community has marginalized knowledge and theories from non-Western perspectives, (Myers et al., 2020) and the rich knowledge developed outside of non-Western societies is 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.

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 understanding cause-and-effect relationships (Snively & Corsiglia, 2016). Such similarities could be leveraged in a way to enable harmonious and complementary co-application.

Our exploration of the research 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 leverage the value of Indigenous knowledge as justificatory knowledge in their projects.

This work addresses 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 in Aotearoa New Zealand. 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) 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. The concept has evolved since, with Gregor and Jones (2007) arguing for merging the kernel theories of the product and process into a single concept of justificatory knowledge. This knowledge gives a basis and explanation for the design. Theory-driven (*ex ante*) design science has maintained its focus on formalized kernel theories to uphold and demonstrate rigour in the project, such that they are now integral to artifact development in IS (Goldkuhl, 2004).

Given the importance of kernel theories, Western-oriented research has examined how to use them and translate them into (1) meta-level knowledge that can guide design in the IS discipline, or (2) artifacts themselves. Goldkuhl (2004) shows 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 different mechanisms to operationalize kernel theories. Their work highlights the various ways that kernel theories have been used in design science projects.

From an Indigenous perspective, kernel theories are a vestige of Western colonial science that do not fully appreciate the value of Indigenous knowledges within design science projects. 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 existing perceptions have been devised largely from Western perspectives (Smith, 2021). 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, 2023).

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). The knowledge is transcultural, systemic, and adapts to changes in environmental conditions over time (Battiste, 2005). Indigenous knowledge is performative — the product of human movement, actions, practices, and protocols — and is embodied in people, their activities, relationships and in their tools, artifacts, and technology (Turnbull, 2009). Indigenous knowledge is also inherently tied to land, including the landscapes and ecosystems where the knowledge is developed and shared (Battiste, 2005) and is fundamentally relational (Turnbull, 2009), built from relationships first between people and the land, and then between people themselves (Tynan, 2021). Finally, Indigenous knowledge systems do not interpret reality following a linear conception of cause-and-effect relationships, but rather through multidimensional relationships and interactions (Mazzocchi, 2006). Stories are culturally nuanced ways of knowing among Indigenous communities (Hunt, 2014). Storytellers, knowledge keepers, and elders play important roles in remembering the collective past and transmitting knowledge (Bastien & Coraiola, 2023).

When researchers inform the design of an artifact using Indigenous knowledge, they must recognize 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 (Smith, 2021; Tynan, 2021). Despite the differences, Indigenous knowledge has complementarities to contemporary scientific knowledge (Turnbull, 2009) that can be useful for addressing important problems. 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 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). With Two-Eyed Seeing, one learns 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 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). Being able to seamlessly weave between knowledge systems and appreciating the strengths of each one enables a more comprehensive understanding of complex issues and the development of contextually 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 has 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. 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. The first is direct integration where there is no knowledge capture other than what is reflected in the artifact. The 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 spans three similar operation spaces, which 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 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 design domain can be applied in the instantiation space, where artifacts are created for specific contexts.

We propose that Indigenous knowledge can be effectively leveraged within artifact design in three main ways. The first option is a direct integration (path A) where Indigenous knowledge manifests 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 (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 contributions 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.

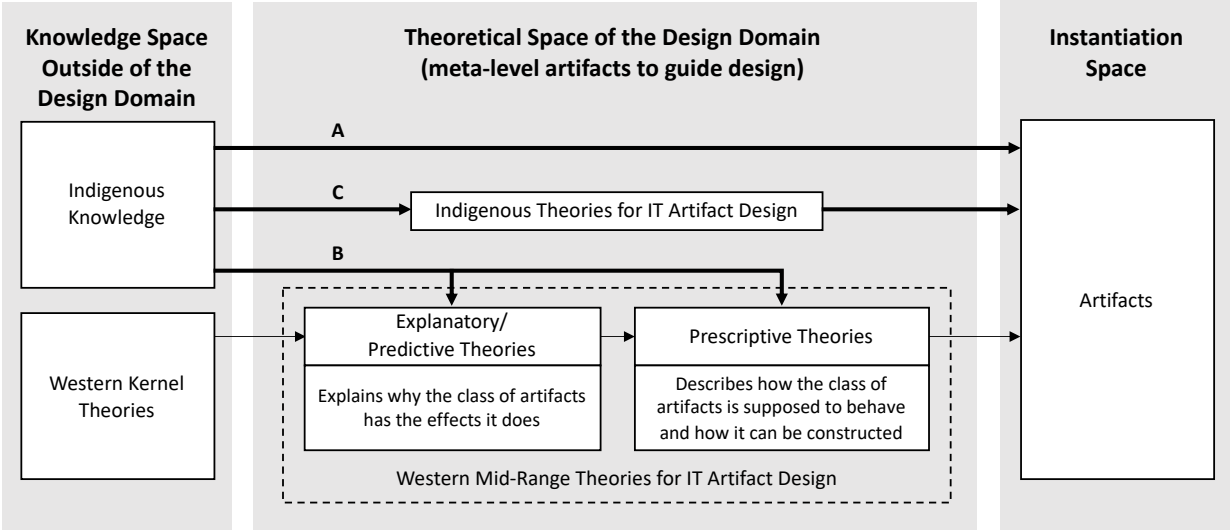

Figure 1. Indigenous knowledge integration framework for design science research

The third path (path C) involves the creation of Indigenous meta-level artifacts, which could include IS design theories 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 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). In 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 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 incorporated directly into artifacts.

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

An example of path B comes from the development of design principles for IT artifacts from Steen (2022) based on insights drawn from Kimmerer (2015) from outside of the design domain. In the book *Braiding Sweatgrass: Indigenous Wisdom, Scientific Knowledge and the Teaching of Plants*, Kimmerer (2015) shares stories 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 their relationship with the rest of the living world. A key lesson is the notion of "honorable harvest" of which Kimmerer

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 adapted by Steen (2022) who used analogical reasoning to apply it to 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 to create fair and open algorithms where we “minimize harm” and “share with others” (Steen, 2022).

4.3 Path C: Creating Indigenous theories for IT artifact design

Design research following the approach of path C are emerging, including the works Mills and Regenbrecht (2023) and Shedlock and Hudson (2022). Here, we use the latter as our example. Shedlock and Hudson (2022) developed the *Kaupapa Māori Modelled IT Artefact* model, a procedure for organizing an Indigenously framed IT artifact (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 represents the core *connection* of the three other dimensions, while specialized working knowledge remains within each dimension.

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 parties involved in defining 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 with communal interactions as a mode of maintaining relationships of accountability early in the IT artifact lifecycle (Shedlock & Hudson, 2022).

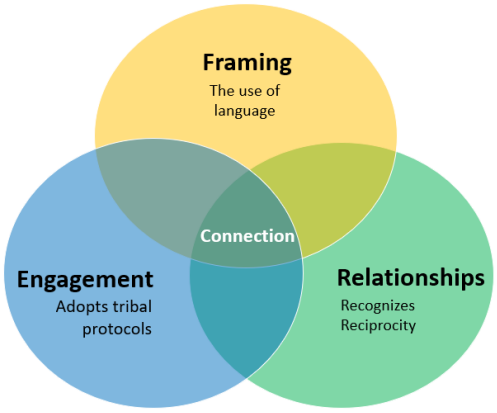

Figure 2. Kaupapa Māori Modelled IT Artefact model

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).

5. 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 is 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 guided its creation. 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.

To provide further context for this case, one of the authors consider themself to be of Indigenous Māori descent. As a direct descendant, they consider themself to be embedded in an Indigenous upbringing linked to tribal chiefs who fought on the outward parts of the palisades and chiefs who fought on the inner parts of the palisades during the battle of Te Ruapekapeka pa. This author shows their intended orientation towards Indigenous autonomy by applying empirically based ideologies through shared Indigenous relationships, past academic journey, and life learnings and failures that make up the broad knowledge base of their Indigenous journey to date. They are imbedded with the learnings of indigeneity and these are the underpinning beliefs that drive their actions that bring their Indigenous aspirations into the future as central motivations pursued for this study – building Indigenous knowledge into the construction of the IT artifact. We present one of such artifacts below.

5.1. The carronade as a tribal treasure

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.

Residing on Te Ruapekapeka Pa site is a carronade (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 Māori 400 warriors stood against a British force of 1600 servicemen and their 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 warriors opposing the British force) had artillery pieces positioned at the rear and forward positions of the battle site. However, both pieces were damaged early in the battle and were rendered ineffective and unusable.

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. It is a symbolic relic linked to the actual battle and a time of unsettled change in New Zealand. The carronade is a living representation of those times that have been discussed and deliberated as part of Te Ruapekapeka's story and the historic beginnings of New Zealand.

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

5.2 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 within the community, empower the community to ask questions, and highlight key aspects of the 3D model carronade.

In working with the Te Ruapekapeka community and applying the *Kaupapa Māori Modelled IT Artefact* model, important considerations were raised about 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.

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 (Figure 4).

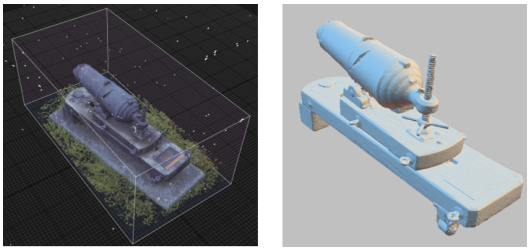

Figure 4. Rendered 3D model in Reality Capture

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.

In the ***third iteration***, the finer details of the carronade were re-explored 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 was done to better define 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 prepared 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)

6. 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 repeat colonial practices where Indigenous knowledge is taken and used (Tynan, 2021) without consideration of the local communities and involvement of knowledge keepers. Leveraging 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.

We also note that the terminologies commonly used in design science are colonial in nature – these include kernel theories, artifacts, and instantiations. Researchers should be mindful in using these terms and further work is needed examine these concepts at a deeper level to understand how they constrain the application of Indigenous knowledges.

IS are modern day artifacts that are culture-ingrained. 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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